



DRAFT MtBE TREATABILITY STUDY WORK PLAN AOC F SITE 1738



For NAVAL ACTIVITY PUERTO RICO EPA I.D. No. PR2170027203 CEIBA, PUERTO RICO





Prepared for:

Department of the Navy NAVFAC SOUTHEAST *North Charleston, South Carolina*

Prepared by:

Baker

Michael Baker Jr., Inc. Moon Township, PA

Contract No. N62470-10-D-3000 DO JM01

February 18, 2011

IQC for A/E Services for Multi-Media Environmental Compliance Engineering Support

DRAFT

MtBE TREATABILITY STUDY WORK PLAN AOC F SITE 1738

NAVAL ACTIVITY PUERTO RICO EPA I.D. NO. PR2170027203 CEIBA, PUERTO RICO

FEBRUARY 18, 2011

Prepared for:

DEPARTMENT OF THE NAVY NAVFAC SOUTHEAST

North Charleston, SC

Under:

Contract No. N62470-10-D-3000

Prepared by:

MICHAEL BAKER JR., INC.

Moon Township, PA

I certify under penalty of law that I have examined and am familiar with the information submitted in this document and all attachments and that this document and its attachments were prepared either by me personally or under my direction or supervision in a manner designed to ensure that qualified and knowledgeable personnel properly gather and present the information contained therein. I further certify, based on my personal knowledge or on my inquiry of those individuals immediately responsible for obtaining the information, that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowingly and willfully submitting a materially false statement.

Signature:	 	
Name:		
Title:		
Date:		

TABLE OF CONTENTS

				<u>Page</u>
LIST	OF AC	CRONYM	IS AND ABBREVIATIONS	v
1.0			TON	
	1.1		Description and History	
	1.2		escription and History	
	1.3		us Investigations	
	1.4		For the Treatability Study	
	1.5		ives	
	1.6	Organi	zation of the Treatability Study Work Plan	1-4
2.0	CUR	RENT C	ONDITIONS	2-1
	2.1	Curren	t Site Conditions	2-1
	2.2	Geolog	gy/Hydrogeology	2-1
		2.2.1	Geology	2-1
		2.2.2	Hydrogeology	2-1
		2.2.3	Aquifer Conditions	2-2
	2.3	Focus	Area For Treatability Study	2-2
3.0	SCO	PE OF T	REATABILITY STUDY	3-1
•••	3.1		ew of the In-Situ Chemical Oxidation Process	
	3.2		nstallation	
		3.2.1	Injection Well Installation	
		3.2.2	Monitoring Well Installation	
	3.3		ment and Materials	
	3.4		1 Installation and Start-Up	
	3.5		n Operation and Maintenance	
	3.6	•	ing and Analysis	
	2.0	3.6.1	Subsurface Soil Sampling Program	
		3.6.2	Groundwater Sampling Program	
		3.6.3	Field Data Collection Program	
		3.6.4	Air Monitoring Program	
	3.7		y Assurance/Quality Control	
		3.7.1	Trip Blanks	
		3.7.2	Equipment Rinsates	
		3.7.3	Field Blanks	
		3.7.4	Field Duplicates	
		3.7.5	Matrix Spike/Matrix Spike Duplicates	
	3.8		Treatability Study Considerations	
	3.0	3.8.1	Site Clearing	
		3.8.2	Utility Clearance	
		3.8.3	Investigation Derived Waste Management	
		3.8.4	Decontamination	
		3.8.5	Surveying	
			, 0	

TABLE OF CONTENTS

(continued)

4.0	REP	ORTING	4-1
	4.1	Introduction	4-1
	4.2	Background	4-1
	4.3	Physical Characteristics of Study Area	4-1
	4.4	MtBE Treatability Study Activities	4-1
	4.5	Physical Results	
	4.6	Analytical Results	
	4.7	Conclusions and Recommendations	4-2
	4.8	References	4-2
5.0	SCH	EDULE	5-1
6.0	PRO	OJECT MANAGEMENT	6-1
	6.1	Project Team Responsibilities	6-1
	6.2	Field Reporting Requirements	6-1
7.0	REF	ERENCES	7-1
		LIST OF TABLES	
1-1		andwater Quality Parameters – Site 1738	
1-2	Posit	tive Detections of Natural Attenuation Parameters – Site 1738	
3-1	Sumi	mary of Sampling and Analytical Program – Environmental Samples	
3-2		nod Performance Limits – Appendix IX Compound List and CRQL	
3-3		mary of Sampling and Analytical Program – QA/QC Samples	
		LIST OF FIGURES	
1-1		onal Location Map	
1-2		Location Map	
1-3	Site 1	1	
1-4	MtB	E Concentrations vs. MNA Event	
2-1	Loca	tion of Focus Area For Treatability Study	
3-1		osed Injection Well, Monitoring Well, and Soil Boring Locations	
3-2		-Ox® Injection Point	
3-3	Cher	nical Oxidation System Process Flow Diagram	
5-1	Prop	osed Project Schedule	
6-1	Proje	ect Organization	

TABLE OF CONTENTS

(continued)

APPENDICES

- A In-Situ Chemical Oxidation Design Parameters
- B Success Stories Using Chemical Oxidation Technology

LIST OF ACRONYMS AND ABBREVIATIONS

AFWTF Atlantic Fleet Weapons Training Facility

AOC Area of Concern

Baker Environmental, Inc./Michael Baker Jr., Inc.

bgs Below Ground Surface

BRAC Base Realignment and Closure

BTEX Benzene, Toluene, Ethylbenzene and Xylenes

C Celsius

CERCLA Comprehensive Environmental Response Compensation and Liability Act

CERFA Community Environmental Response Facilitation Act

COD Chemical Oxygen Demand

DO Delivery Order

DRO Diesel Range Organics

foc Fraction of Organic Carbon

ft/day Feet per Day ft/ft feet per foot

GES Groundwater & Environmental Services, Inc.

GPS Global Positioning System
GRO Gasoline Range Organics

HSA Hollow stem augers

IDW Investigation Derived Waste ISCO In-Situ Chemical Oxidation

lbs/day Pounds per Day

LEL Lower Explosive Limit

LNAPL Light Non-Aqueous Phase Liquid

mg/kg Milligram per Kilogram

MNA Monitored Natural Attenuation
MS/MSD Matrix Spike/Matrix Spike Duplicate

msl mean sea level

MtBE Methyl Tertiary Butyl Ether

NAPR Naval Activity Puerto Rico

NAVFAC Naval Facilities Engineering Command

NSRR Naval Station Roosevelt Roads NTR Navy Technical Representative

O&M Operation and Maintenance

OH• Hydroxyl Radical

ORP Oxidation Reduction Potential

OVM Organic Vapor Monitor

LIST OF ACRONYMS AND ABBREVIATIONS

(continued)

PID Photoionization Detector
PLC Programmable Logic Controller
PMO Program Management Office

ppm Parts Per Million

PREQB Puerto Rico Environmental Quality Board

QA/QC Quality Assurance/Quality Control

RCI Reactivity, Corrosivity, and Ignitibility RCRA Resource Conservation and Recovery Act

RFI RCRA Facility Investigation

ROI Radius of Influence

RSL Regional Screening Level

SE Southeast

SVE Soil Vapor Extraction

TCLP Toxicity Characteristic Leaching Procedure

TPH Total Petroleum Hydrocarbon

μg/L Micrograms per Liter

USCS Unified Soil Classification System

USEPA United States Environmental Protection Agency

UST Underground Storage Tank

VOC Volatile Organic Compound

1.0 INTRODUCTION

This document presents the activities required for the performance of a treatability study to evaluate the reduction of methyl tertiary butyl ether (MtBE) through the use of in-situ chemical oxidation (ISCO) in the groundwater at Area of Concern (AOC) F, Site 1738, located at Naval Activity Puerto Rico (NAPR), Ceiba, Puerto Rico.

This work plan has been prepared by Michael Baker Jr., Inc. (Baker), for the Navy Base Realignment and Closure (BRAC) Program Management Office (PMO) Southeast (SE) office under contract with the Naval Facilities Engineering Command (NAVFAC), SE (Contract Number N62470-10-D-3000, Delivery Order [DO] JM01). This work plan was developed in accordance with the Resource Conservation and Recovery Act (RCRA) § 7003 Administrative Order on Consent (United States Environmental Protection Agency [USEPA] Docket No. 02-2007-7301 [USEPA, 2007]). The work will be implemented in accordance with the Final RCRA Facility Investigation (RFI) Management Plans (Baker, 1995), with updates as indicated in this work plan.

1.1 NAPR Description and History

NAPR occupies over 8,800 acres on the northern side of the east coast of Puerto Rico, along Vieques Passage with Vieques Island lying to the east about 10 miles off the harbor entrance (Figure 1-1). NAPR also occupies the immediately adjacent islands of Piñeros and Cabeza de Perro, as presented on Figure 1-2. The northern entrance to NAPR is about 35 miles east along the coast road (Route 3) from San Juan. The property consists of 3,938 acres of upland (developable) property and 4,955 acres of environmentally sensitive areas including wetlands, mangrove, and wildlife habitat. The closest large town is Fajardo (population approximately 41,000), which is about 5 miles north of NAPR off Route 3. Ceiba (population approximately 18,000) adjoins the west boundary of NAPR (Figure 1-1).

The facility was commissioned in 1943 as a Naval Operations Base, and finally re-designated a Naval Station in 1957. Naval Station Roosevelt Roads (NSRR) operated as a Naval Station from 1957 until March 31, 2004. NSRR was one of the largest naval facilities in the world with more than 100 miles of paved roads, approximately 1,300 buildings, a large scale airfield (Ofstie Field), a deep water port, and over 30 tenant commands. NSRR played a major role in providing communication support to the Atlantic and Caribbean areas and also served as a major training site for fleet exercises.

Section 8132 of fiscal year 2004 Defense Appropriations Act, signed into law on September 30, 2003, directed that NSRR be disestablished within 6 months, and that the real estate disposal/transfer be carried out in accordance with procedures contained in the BRAC Act of 1990. This legislation required that the base closure be conducted in accordance with the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), as amended by the Community Environmental Response Facilitation Act (CERFA). NSRR has undergone operational closure as of March 31, 2004 and has been designated as Naval Activity Puerto Rico. The mission of NAPR is to protect the physical assets remaining, comply with environmental regulations, and sustain the value of the property until final disposal of the property. NAPR will continue until the real estate disposal/transfer is completed.

The USEPA issued a RCRA § 7003 Administrative Order on Consent (USEPA Docket No. RCRA-02-2007-7301 [USEPA, 2007]) to NAPR. The Order sets out the Navy's corrective action obligations under RCRA and replaces the 1994 RCRA permit for NAPR. Following a public comment period, the Consent Order became effective on January 29, 2007.

1.2 Site Description and History

Site 1738 is located on the eastern side of NAPR, in an industrial area of NAPR, as depicted on Figure 1-2. The site was used from 1959 to 1996 as an industrial gasoline station with four underground storage tanks (USTs), as depicted on Figure 1-3. Three of the USTs (10,000 gallon capacity each) contained unleaded gasoline, and the fourth UST (550 gallon capacity) contained waste oil. The four tanks were reportedly removed from the site in 1996 (BBI, 1999).

During the UST removal conducted in 1996, total petroleum hydrocarbon (TPH) concentrations ranging from 2,468 to 3,486 milligrams per kilogram (mg/kg) were found in the soil. Because these concentrations were above the Puerto Rico Environmental Quality Board (PREQB) target level, a site characterization was performed on the environmental media in the area of the tank removal (BBL, 1999). Figure 1-3 indicates the placement of the soil borings and monitoring wells at the site.

The results of the site characterization indicate that elevated concentrations of TPH were present in the subsurface soil and groundwater, and elevated concentrations of benzene, toluene, ethylbenzene and xylenes (BTEX) were detected in the groundwater. In addition, light non-aqueous phase liquid (LNAPL) was detected in well 1738MW02. The site characterization recommended skimming of free product at well 1738MW02; however, no corrective measures for soil were recommended, indicating that natural attenuation processes would deplete the highest hydrocarbon concentration area.

A monitored natural attenuation program (MNA) was initiated for the groundwater at Site 1738 in 2000. From December 2000 through March 2008, the groundwater was sampled and analyzed for TPH and BTEX. MtBE was added to the analytical sampling program at Site 1738 in 2008 with the development of a new work plan for the implementation of the MNA program at Site 1738 (Baker, 2008).

As proposed in the Final MNA AOC F-Year 7 Annual Report (December 2009), and in the Navy's response to USEPA comments dated September 29, 2009, a work plan was developed to investigate the MtBE contamination at Site 1738 independently from the MNA program. The Site 1738 MtBE Investigation Work Plan was approved by USEPA on May 11, 2010. In addition to defining the lateral extent of MtBE in groundwater, the work plan also identified conducting a pilot-scale treatability study as one of the project objectives. Subsequent field investigation activities were conducted in September 2010 in support of the Draft MtBE Investigation Report AOC F-Site 1738 (Baker, 2011).

The Draft MtBE Investigation Report recommended additional monitoring wells at Site 1738 to further define the lateral extent of MtBE in groundwater. The report also recommended additional soil borings to investigate existing MtBE concentrations in the soil. Therefore, additional subsurface soil and groundwater samples will be collected in conjunction with the treatability study. Proposed sample locations, are presented in Section 3.0 of this work plan.

A detailed description of the current site conditions is given in Section 2.1.

1.3 <u>Previous Investigations</u>

Sampling results obtained from May 2008 through August 2010 indicate high concentrations of MtBE in the groundwater in the vicinity of the former pump island and the former gasoline station. A summary of these results is included on Figure 1-4. Further, samples analyzed for dissolved oxygen at the site indicate that the groundwater at the site is anaerobic (Table 1-1). Dissolved

oxygen concentrations obtained at the groundwater monitoring wells indicate levels below 1 part per million (ppm) and negative oxidation reduction potential (ORP) readings. The preferred degradation pathway for MtBE in groundwater appears to be aerobic (ITRC, 2005). Anaerobic bio-degradation has been documented to occur given an environment that provides the anaerobic bacteria the substrate it requires to break down the MtBE. Because anaerobic bacteria require a specific environment for MtBE degradation, anaerobic degradation of MtBE has not been widely observed in groundwater contaminated with MtBE. Further, laboratory bench study tests performed to evaluate the effectiveness of anaerobic bacteria in reducing MtBE levels indicate that, given ideal conditions, the process of MtBE degradation can occur given adequate time and an environment that meets the needs of the anaerobic bacteria. Generally, however, MtBE biotransformation processes are slow and MtBE degrading organisms are difficult to isolate (Youngster, 2009). Because of this, anaerobic biodegradation is not commonly observed.

Results obtained from the September 2010 field investigation conducted at Site 1738 confirm that the highest levels of MtBE occur in the area around monitoring well 1738MW03. The investigation also confirmed the relatively tight permeability of the soil at the site. By obtaining groundwater samples from additional monitoring wells installed as part of the investigation, the limits of MtBE contamination appear to be only partly delineated (Baker, 2011).

As part of the development of this treatability study, specific parameters were collected during the September 2010 field investigation to establish a baseline for the treatability study design. These analytical results are included in this work plan as Appendix A.

1.4 Basis for the Treatability Study

Analytical results obtained from monitoring wells at Site 1738 indicate that MtBE levels are elevated, especially at 1738MW03. As part of the Site 1738 MtBE Investigation Work Plan approved on May 11, 2010, the Navy proposed an approach for evaluating a method to reduce the levels of MtBE in the groundwater through the use of in-situ enhanced bioremediation. Subsequently, additional research into the nature and extent of the contamination and after further evaluating the physical conditions of the site, it appears that the levels of MtBE will be more effectively reduced through the use of an ISCO treatment system. It is anticipated that through the use of in-situ chemical oxidation, the rate of MtBE reduction will be much greater than that of in-situ enhanced bioremediation alone. A patented ISCO technology by Groundwater & Environmental Services, Inc. (GES) called Max-Ox® will be studied at the site to evaluate the potential effectiveness of the in-situ technology in addressing residual, dissolved, and adsorbed-phase hydrocarbon impact and MtBE in the groundwater.

A treatability study is proposed to evaluate the effectiveness of injecting ozone/oxygen gas into a network of dedicated injection wells along with compressed air using a large ozone generation system. The low pressure air injection is utilized in conjunction with oxidant injection to aid in dispersion and increase the radius of influence (ROI) at each injection point. This oxidation process has also been proven to promote significant bioremediation, as an additional and secondary remediation technique, outside of the injection area due to significant increases in dissolved oxygen.

1.5 Objectives

The purpose of this Treatability Study Work Plan for Site 1738 is to identify the method and procedures for a treatability study to be conducted in the area impacted by the highest concentrations of MtBE in the groundwater at the site. The objective of the treatability study will be the destruction and reduction of MtBE in groundwater. An additional objective of the treatability study will be to

increase the aerobic conditions in the aquifer with the controlled use of oxygen releasing compounds to the aquifer. This work plan will specify the equipment, sampling, laboratory analysis, and reporting expected during the implementation of the treatability study.

The objectives of the treatability study are to:

- Evaluate the effectiveness of the ISCO technology to reduce dissolved-phase and adsorbedphase petroleum hydrocarbons, specifically MtBE, within the targeted treatment area (i.e., the area affected by the highest concentrations of MtBE in the groundwater);
- Obtain operational and performance data to design a full-scale ISCO application, including injection flow rates, pressures, and other design parameters; and
- Determine the radius of influence of the injection wells to establish appropriate spacing for a full-scale ISCO design.

A combination of pre-study baseline analytical sampling, regularly collected field data during the study, and post-study analytical sampling will be utilized to assess system performance. Pre-study data will be used as a baseline when determining overall contaminant reductions at the conclusion of the treatability study. During the study, groundwater data, including dissolved oxygen content and ORP, will be collected at proximal monitoring wells to determine the radius of influence of the injection wells. System information including injection flow rates and pressures will be recorded throughout injection activities to ensure these parameters are optimized during full-scale implementation.

1.6 Organization of the Treatability Study Work Plan

This work plan is organized into seven sections. Section 1.0 of this document presents a brief summary of the background of NAPR, the history and previous investigations at Site 1738, the basis for the treatability study, and objectives of this treatability study work plan. Section 2.0 provides a description of the current conditions of the site, as well as the focus area of the treatability study. Section 3.0 provides a description of the treatability study that will be performed at the site. The treatability study will include installation of remediation equipment, monitoring well installation, groundwater sampling and analysis, as well as other treatability study considerations. The reporting activities that will be conducted following the completion of the treatability study are described in Section 4.0. Section 5.0 discusses the proposed project schedule that will be followed for this treatability study. The site management structure that will be utilized during this treatability study, including project team responsibilities and field reporting requirements, is presented in Section 6.0, while Section 7.0 presents the work plan references.

2.0 CURRENT CONDITIONS

The following sections provide a brief discussion of the current conditions that exist at Site 1738, the site geology and hydrogeology, and the focus area for treatability study.

2.1 Current Site Conditions

Site 1738 is located along Forrestal Drive, across from JP-5 Hill and the DRMO facility (Buildings 1973, and 2009, 2009A, and 2009 B, C, and D). The entire site is approximately 2.1 acres in size (most of which is heavily vegetated). There are no structures located on site.

Site 1738 is comprised of two distinct areas; an upgradient (raised surface/fill) area and a downgradient area. The upgradient area is not heavily vegetated as the site is bisected by an overhead utility right-of-way. The upgradient area includes monitoring wells 1738MW01, 1738MW02, 1738MW03, 1738MW04, 1738MW11, and 1738MW12. Ground elevations in this upgradient area range between approximately 22 and 25 feet mean sea level (msl) (i.e., 122 and 125 feet datum). The downgradient area, in contrast, does not contain fill and is heavily vegetated with secondary growth. This area includes monitoring wells 1738MW05, 1738MW05L, 1738MW05R, 1738MW06, 1738MW07, 1738MW08, 1738MW09, and 1738MW10. Ground elevations in this down gradient area range between approximately 7 and 12 feet msl (Baker, 2011).

2.2 Geology/Hydrogeology

The following sections discuss the geology and hydrogeology in the vicinity of Site 1738.

2.2.1 Geology

Site 1738 is located in an upland area within the Forrestal Area of the base. The upland areas of NAPR include the hills encompassing the Tow Way Fuel Farm and hospital areas, and the hills encompassing the area behind the Exchange, the former Atlantic Fleet Weapons Training Facility (AFWTF) Command, and the Bundy area. These upland areas are underlain by bedrock (predominately Gabbro) and exhibit varying degrees of weathering. Typically, the bedrock is overlain be a relatively thin residual soil (i.e., residuum). Residuum is unconsolidated soil, originating from weathered-in-place bedrock. This residuum generally consists of clay, silt, and/or sand. Below the residuum, chemically weathered bedrock or saprolite, typical in hot humid climates, is present to some degree. This "saprolite" retains the bedrock structure but is weathered to a brittle consistency.

The southern portion of Site 1738 (i.e., the area where the former gasoline station was located) is underlain by silt and clay fill material with some areas containing sand and gravel where the former tank pits and fuel lines were located. The fill material appears to lie on top of residuum and saprolite. The fill thickness was approximately 7.0 feet at 1738MW11 and 18 feet at 1738MW03. The fill material is not present in the northern portion of the site. Groundwater was observed near the fill/saprolite interface and flows to the north were the topography drops and groundwater is close to or at the ground surface.

2.2.2 Hydrogeology

The groundwater flow at upland area Site 1738 is toward the north with a hydraulic gradient of approximately 0.006 feet per foot (ft/ft). Groundwater was observed at the interface with the fill and saprolite in the area of the former gas station (Baker, 2011).

According to the site characterization report, groundwater flow at Site 1738 is controlled by several factors, including topography and areas of pea gravel (former UST locations). Some mounding of the water table occurs in the former UST locations (near Monitor Wells 1738MW01 and 1738MW02). The falling head slug test results indicated hydraulic conductivities ranging from 0.6 feet per day (ft/day) to 2.6 ft/day, again confirming the relatively tight nature of the soils at NAPR (BBL, 1999).

MNA results indicate that the groundwater flow direction at the site can be variable, with groundwater mounding at 1738MW02, and may flow either to the north or south from there. Due to the slope of the ground surface from the south to the north, overall groundwater flow is likely to be toward the north. There is a clay layer at the site of very high plasticity which would control movement of groundwater contamination to lower elevations. However, at location 1738MW03, this clay layer is not present due to the removal of the UST and the placement of pea gravel and pea gravel mixed with site soil. The well is screened in the lower plasticity saprolite. This removal of the clay layer implies that the site contamination may have migrated downward under the clay layer (Baker, 2008).

2.2.3 Aquifer Conditions

Figure 1-4 depicts the historical distribution of MtBE in groundwater at wells 1738MW01, 1738MW02, 1738MW03, and 1738MW05R. MtBE had been detected in all wells at the site prior to the September 2010 field event. The concentrations exceed the USEPA Tap Water Regional Screening Level (RSL) of 12 micrograms per liter (μg/L) and the PREQB Target Level of 20 μg/L at all wells. The MtBE concentrations have been highest at the well closest to the highest levels of MtBE identified in the groundwater at the site, near 1738MW03 (9,800 μg/L). Prior to the September 2010 field event, the extent of MtBE had not been defined by the existing monitoring well network. After reviewing the latest analytical results from September 2010 field effort, the extent of MtBE contamination in groundwater to the northwest and northeast appears to be only partly determined (Baker, 2011). MtBE has not been identified in the mangrove located further downgradient of the site. Three surface water samples were collected for MtBE analysis during the Year 6/Quarter 2 event and MtBE was not detected.

Tables 1-1 and 1-2 present the groundwater quality parameters and the positive detections of natural attenuation parameters, respectively, for Site 1738 obtained during the Year 8/Quarter 2 MNA event. Under reducing biodegradation conditions within a petroleum contamination plume, dissolved oxygen and sulfate would be expected to be depleted with respect to background conditions. Likewise dissolved iron (a surrogate for Fe⁺²) and methane would be expected to be elevated with respect to background conditions. As shown, the geochemical indicators at 1738MW03 are exhibiting some characteristics of a reduced aqueous environment. Elevated dissolved iron and methane and depleted sulfate are all present in this location. This reduced environment is characteristic of locations where fuel contamination is present and biodegradation is occurring. Remnants of reduction are apparent at 1738MW01 and 1738MW02, with elevated dissolved iron, but no consistent footprint is seen at these two locations. This is consistent with previous sampling events. ORP levels obtained during the Year 8/Quarter 2 MNA event are negative in most wells, which would be consistent with reducing conditions (Baker, 2010).

2.3 Focus Area For Treatability Study

The focus area for the groundwater treatment to be evaluated during this MtBE treatability study is identified on Figure 2-1 as the area containing the highest levels of MtBE in the groundwater, based on results obtained during previous groundwater sampling investigations performed at the site. The

focus area is approximately 70 feet by 50 feet in size, surrounding 1738MW03. A network of dedicated injection wells will be installed. For the purposes of this work plan, the water table was assumed to be 20 feet below ground surface (bgs) with native soil lithology consisting of silt and clay. Based on ROI data observed during activities at sites with similar lithology, the effective ROI at each well injection point is assumed to be 15 feet. The wells will therefore be placed approximately 30 feet apart to provide a sufficient injection well network.

3.0 SCOPE OF TREATABILITY STUDY

In order to execute the treatability study, a network of dedicated injection wells will be installed in the area which contains the highest levels of MtBE, which appears to be the area near existing monitoring wells 1738MW01, 1738MW02, and 1738MW03. The treatability study will include the evaluation of a continuously operating ozone generation system. A mixture of ozone, oxygen, air and hydrogen peroxide will be injected into a network of dedicated injection wells using an ozone generation system capable of producing up to 80 pounds per day (lbs/day) of ozone. The low pressure air injection is utilized in conjunction with the ozone/oxygen injection to aid in dispersion and to increase the radius of influence at each injection point. In addition to the ozone/oxygen/air injection, a hydrogen peroxide solution will be injected into the injection wells at rates up to 50 gallons per day.

3.1 Overview of the In-Situ Chemical Oxidation Process

ISCO using hydrogen peroxide and ozone has been proven to be an effective remediation technology for the oxidation of organic contaminants in subsurface soils and groundwater (ITRC, 2001). Petroleum hydrocarbons and MtBE, as are present at this site, are amenable to remediation by this technology due to their ability to be directly oxidized by hydrogen peroxide and ozone and also through subsequent biological degradation activity. The oxidation process breaks down the organic contaminants into naturally occurring compounds. Hydrogen peroxide reacts with ozone and/or iron in the subsurface to form the hydroxyl radical (OH•). The hydroxyl radical is a stronger oxidant than either ozone or hydrogen peroxide individually. The dissolved and adsorbed hydrocarbons present have relatively high reaction rate constants with the hydroxyl radical and are readily susceptible to breakdown through this process.

A secondary benefit of the ozone/peroxide injection process is the significant increase in dissolved oxygen concentrations within the injection area, as well as areas downgradient of the highest MtBE concentration area to enhance bioremediation. This can be a significant enhancement to the remediation process, because the leading edge of the dissolved-phase plume may not need to be remediated directly. Typically, the area impacted is addressed with a continuously-operating ISCO system for significant contaminant reduction, while the downgradient dissolved phase is addressed via enhanced bioremediation. The significant increase in dissolved oxygen is typically observed for various reasons:

- Industrial ozone generators utilize close to 99% oxygen as the carrier gas and convert nearly 10% of the oxygen to ozone. As a result, the ozone generators have the capacity to inject close to 10% ozone and 89% oxygen; and
- Ozone and hydrogen peroxide break down to form dissolved oxygen.

The ISCO method of groundwater treatment was selected for Site 1738 based on the following:

- Rapid destruction/degradation of contaminants (measurable reductions in weeks or months);
- Produces no significant wastes [volatile organic compound (VOC) off-gas is minimal];
- Oxidants are capable of completely oxidizing MTBE;
- Reduced operation and monitoring costs;
- Compatible with monitored natural attenuation and has been proven to enhance aerobic biodegradation of residual hydrocarbons (ITRC, 2001).

The site geology consisting of primarily silt and clay with some sands mixed into the fill in the vicinity of 1738MW03, 1738SB105, and 1738MW02 is well suited for the ISCO technology.

Several sites with similar geologic and groundwater quality conditions have been remediated using ISCO (peroxide and ozone) with positive results (http://clu-in.org/products/mtbe/). Other case studies using this technology are included with this work plan as Appendix B.

Enhanced in-situ biodegradation pilot tests in groundwater plumes have been used at other NAPR sites (SWMUs 54 & 55) with varying results. It should be noted that the Max-Ox® system uses a more powerful oxidizer and has been proven effective in treating MtBE in groundwater.

3.2 Well Installation

A network of dedicated injection wells, as well as additional monitoring wells, will be installed at Site 1738 as depicted on Figure 3-1. The following sections describe how the injection and monitoring wells will be installed, the proposed locations, and development procedures.

3.2.1 Injection Well Installation

Based on the available data, it is estimated that up to five injection wells (1738IW13 through 1738IW17) will be installed. Liquid hydrogen peroxide and gaseous ozone/oxygen will be coinjected via a nested injection well configuration to provide advanced oxidation (formation of hydroxyl radicals), increased contaminant contact, and increased radius of influence.

In order to ensure compatibility with the oxidants to be injected, the wells will be constructed using stainless steel well screen and casing. The radius of influence is assumed to be 15 feet, based on the underlying native materials at the site. The injection wells will be placed approximately 30 feet apart to provide a sufficient injection well network as shown in Figure 3-1.

Nested injection wells will be constructed as shown in Figure 3-2 by installing two-1" diameter steel points (each point will be constructed to allow for injection of ozone/oxygen/air and hydrogen peroxide) into an eight-inch diameter borehole. The vertical separation of the screens within the borehole will be field-determined during installation, but will be placed between two and five feet apart. Sand pack will be placed surrounding the lower screen and to a depth of at least one foot above the top of the lower screen. A bentonite seal (minimum of one foot thick) will be placed above the sand pack surrounding the stainless steel screen to prevent short-circuiting. Following the installation of the bentonite seal, the upper screen will be installed. Sand pack will be placed surrounding the screen and up to at least one foot above the top of the upper screen. Following the application of a minimum one foot thick bentonite seal, the borehole will be filled to the surface with concrete grout. All wells will be finished within flush-mounted well vaults. The maximum depth of the nested injection wells is expected to be approximately 35 feet.

Borehole advancement for the injection wells will be performed utilizing hollow-stem auger (HSA) drilling techniques. As material is recovered from each borehole, the material will be characterized using the Unified Soil Classification System (USCS) and the information will be recorded in a field log book. Soil samples will be screened with a photoionization detector (PID) to determine the relative presence or absence of VOCs. Upon completion of the drilling activities, subsurface drilling logs will be completed for each well.

Following installation of the injection wells, well development activities will be completed to establish connectivity with the aquifer. An air-lifting technique will be utilized to complete the development and prepare the wells for remediation. Surging with compressed air is done by injecting a sudden charge of compressed air into the well so that water is forced through the well screen and gravel pack. Air lifting will start at the top of the screened interval and move downward until the sand

pack throughout the screened interval is developed. Once the air lifting is initiated, air flow rates will be adjusted as needed to facilitate the removal of fines and until the discharged water is sediment free.

3.2.2 Monitoring Well Installation

As shown on Figure 3-1, five additional monitoring wells (1738MW18 through 1738MW22) are proposed to be installed at Site 1738. Monitoring well 1738MW18, located near the center of the nested injection wells, will function as an observation well during the treatability study. Monitoring wells 1738MW19 through 1738MW22 are proposed to be installed based on recommendations from the Draft MtBE Investigation Report (Baker, 2011). Well 1738MW19 will be installed to verify the integrity of 1738MW02, located approximately 20 feet west. Well 1738MW20 is proposed to be installed southwest of the site beyond 1738MW11 to identify up- and side-gradient conditions. Monitoring well 1738MW21 will be installed approximately 200 feet west of 1738MW02, which is down gradient of 1738MW11. To further identify the eastern extent of MtBE in groundwater, additional well 1738MW22 will be installed east of 1738MW10. Well installation and development procedures for the five additional monitoring wells will follow the approved specifications in the Monitored Natural Attenuation Work Plan for AOC F (Baker, 2008).

3.3 Equipment and Materials

The chemical oxidation system will be housed within an enclosed trailer or container. The system will include the oxygen/ozone and hydrogen peroxide injection systems with individual controls for each injection well. A process flow diagram depicting the oxidation system is included with this work plan as Figure 3-3.

The ozone system components include an air compressor, pressure swing adsorption unit, and ozone generator. The air compressor and pressure swing adsorption unit are utilized to generate oxygen and are commonly used with oxygen/ozone generators which are a safer method of providing ozone than the alternative method of storing oxygen tanks on site. The air produced by the compressor is directed into a pressure swing adsorption unit which adsorbs the nitrogen naturally present in the air stream, resulting in an oxygen-rich air stream to feed the ozone generator. The nitrogen adsorption unit periodically exhausts small volumes of nitrogen back into the atmosphere. The flow of the oxygen stream is monitored by a flow indicator. A low flow alarm will cause the air compressor to shut down to avoid a leak in the system or malfunctioning oxygen generation equipment. The flow is also transmitted to a flow controller which operates a solenoid valve to ensure a constant flow is delivered to the ozone generator. Downstream of the flow indicator is a pressure indicator with a high pressure alarm and pressure relief valve. The oxygen/ozone output stream will be a mixture of approximately 90% oxygen and a maximum of 10% ozone.

As a safety precaution, the system is equipped with an exhaust fan. The exhaust line also contains an ozone detector. The exhaust is directed through an ozone destruction medium prior to discharge into the atmosphere. Therefore, if an ozone line were to leak, the ozone detector would shut down the system and any ozone in the atmosphere would be destroyed prior to being vented from the trailer.

The chemical injection system to be utilized during the treatability study will inject up to 80 pounds per day (lbs/day) of ozone gas and 350 gallons per week of 31% hydrogen peroxide solution. Hydrogen peroxide will be delivered to the site in 55-gallon drums or small totes and staged within secondary containment until transferred into the system holding tank.

The system includes a programmable logic controller (PLC) to control the operation of the ozone, oxygen, air, and hydrogen peroxide injection system. The PLC is used to ensure that injection flow rates at each point are controlled and to pulse the operation of the system to cycle injection wells and flows. A wireless remote telemetry unit will be included with the equipment to provide operational status of the equipment and to notify personnel in the event an alarm condition or process upset occurs. GES will operate and maintain the equipment as required and will make frequent adjustments in order to optimize the performance of the system.

3.4 System Installation and Start-Up

Once the injection wells have been installed, piping has been connected to the equipment compound, and power connections have been completed, start-up of the system will be initiated. A representative from the ozone system manufacturer will be on site to test all ozone system components and calibrate the ozone generator. Leak testing of the ozone generation system will be conducted to ensure no fittings were loosened during the transport and installation of the system. Each of the system alarms and interlocks will be tested to inspect the operation of the injection system. System start-up will occur over a period of one week during which time the ozone system injection rate (lbs/day of ozone) will be gradually increased in a step-wise fashion. During each step, vapor monitoring will be conducted to ensure there are no preferential pathways for ozone, oxygen, or VOCs to travel to the surface. Operational data, including pressure at each injection wellhead, will be recorded and adjustments will be made for optimum system performance.

3.5 System Operation and Maintenance

It is anticipated the ISCO system will operate for a period of approximately 2 months. The duration of the treatability study operation may be adjusted based on results obtained during the operation of the system. Routine system operation and maintenance (O&M) will be required to ensure proper system operation and optimization. O&M of the ISCO system will be conducted on a weekly basis. Typical operational and preventative maintenance activities for the system are detailed below:

Weekly Activities

- Inspect coolant level, inspect and clean chiller pump strainer;
- Inspect / clean coolant filter;
- Inspect for gas, water leaks;
- Check oxygen filter;
- Check / replace container ventilation intake filter;
- Verify operation of drain valves / clean elements;
- Screen venting discharge for VOCs via PID;
- Check moisture separator for accumulated liquid / drain;
- Verify generator operation / voltage / phase / amperage; and
- Record operating data on log sheet.

Monthly Activities

- Check compressor intake filter;
- Check pressure swing adsorber intake filters; and
- Change injection compressor intake filters.

3.6 Sampling and Analysis Program

In order to meet the objectives of the treatability study, subsurface soil sampling analysis, groundwater sampling analysis, field data collection, and air monitoring will be performed as described in the following sections. Sampling and analysis will be completed in accordance with procedures established in the Final RCRA Facility Investigation Management Plans (Baker, 1995).

3.6.1 Subsurface Soil Sampling Program

During injection well drilling activities, one subsurface soil sample (depth to be determined in the field) will be collected from each of the five injection well locations (1738IW13 through 1738IW17) for laboratory analysis of BTEX, MtBE, TPH diesel range organics (DRO)/gasoline range organics (GRO), and fraction of organic carbon (foc). Because the organic content of soil acts as an oxidant sink, assessing and quantifying the amount of organic content of site soil by foc analysis will be utilized to estimate the total oxidant demand within the study area. Analytical methods are identified in Table 3-1.

As part of the recommendations presented in the Draft MtBE Investigation Report (Baker, 2011), four additional soil boring locations (1738SB106 through 1738SB109) are proposed to investigate existing MtBE soil concentrations in the former tank pit area as depicted on Figure 3-1. Subsurface soil samples will also be collected during drilling activities at monitoring wells 1738MW18, 1738MW19, and 1738MW20. At each sampling location, subsurface soil samples for laboratory analysis will be collected at the 2-foot interval immediately above the seasonal high water table and at a depth determined in the field based on PID screening and visual/olfactory observations. Samples will be analyzed for BTEX, MtBE, and TPH DRO/GRO, as presented in Table 3-1. Procedures for the collection of subsurface soil samples will follow the approved specifications in the Monitored Natural Attenuation Work Plan for AOC F (Baker, 2008).

Soil samples will be transferred directly to laboratory provided sample containers that have been prepared with appropriate preservatives by the laboratory. Sample bottles will be labeled with site-specific information and will be packed in coolers and placed on ice to maintain a temperature of 4° Celsius (C). Samples will be shipped next day air to the laboratory for standard turn-around time for all soil samples. Soil quality data will be utilized to refine the estimated quantity of oxidant needed during remediation and provide a pre-remediation baseline of soil conditions in the injection area. All analysis at the laboratory will be performed using current methods as presented in Table 3-2.

3.6.2 Groundwater Sampling Program

Following the installation and development of the injection wells, baseline groundwater samples will be collected from both screened intervals of the nested injection wells. Groundwater samples will be collected from each of the existing and proposed monitoring wells.

All baseline groundwater samples will be collected via low-flow methodology and shipped under proper chain-of-custody for analysis of BTEX, MtBE, and TPH DRO/GRO. A subset of the baseline samples will also be analyzed for physical/geochemical characteristics to facilitate comprehensive evaluation of the ISCO performance. These analyses will include the following parameters, as indicated on Table 3-1:

- Chemical Oxygen Demand (COD) (EPA method 410.1);
- Heterotrophic Plate Count (HPC-SM 9215B);
- Total and dissolved iron (SW 846 method 6010); and
- Carbon dioxide (SM20-4500).

During the treatability study, groundwater sampling will be conducted every two weeks to assess performance of the ISCO system. These interim groundwater samples will be collected from wells 1738MW01, 1738MW02, 1738MW03, 1738MW05R and 1738MW18 via low-flow methodology and shipped under proper chain-of-custody for analysis of BTEX, MtBE, and TPH DRO/GRO.

Post-shutdown groundwater sampling will occur at the conclusion of ISCO operation. The sampling procedures are identical to the baseline groundwater sampling procedure, as previously described. Additionally, four weeks after post shutdown all wells will be sampled for BTEX, MtBE, and TPH DRO/GRO. The results will be used to evaluate the effectiveness of the ISCO system.

Samples will be packed in ice and shipped next day air to the laboratory for standard turn-around time for all groundwater samples, except for the interim samples taken every two weeks. These interim samples will be designated for quick-turn analysis. The laboratory will provide analysis results within 48 hours of sample receipt. Tracking numbers for each shipment will be forwarded to the data manager for assisting in verification of receipt of samples by the laboratory. All analysis at the laboratory will be performed using current methods as presented in Table 3-2.

3.6.3 Field Data Collection Program

In order to evaluate the performance of the ISCO system, the following field-collected data will be obtained from the monitoring wells during system operation for the media and parameters indicated:

Using an YSI 600XL Multi Parameter Water Quality Sonde, the following water column measurements will be made.

- pH
- Temperature
- Oxidation-Reduction Potential
- Dissolved oxygen
- Conductivity

A Hanna HI 98703 Portable Turbidimeter will be used to measure water column turbidity.

Using a Solinst 122 Interface Probe (or equivalent), the depth of groundwater from the top of casing will be measured. Changes in groundwater elevation will be used to monitor the influence of the injection system.

A MiniRAE 2000 PID with 10.6 eV lamp will be used to measure the VOC concentrations, and a QRAE PLUS LEL/O₂/CO/H₂S monitor will be used to measure lower explosive limit (LEL) and oxygen levels, and a Eco Sensor A21ZX ozone detector will measure the ozone.

Pressure indicators will also be periodically attached to monitoring wells to measure induced pressures from the injection activities to aid in the evaluation of the ROI.

3.6.4 Air Monitoring Program

Soil vapor extraction (SVE) will not be implemented as part of the treatability study as it is assumed there are no known utilities or nearby receptors. During injection activities, ambient air measurements at the monitoring wells and injection well wellheads will be performed for total VOCs, ozone, and oxygen on a weekly basis. Monitoring of the headspace of the monitoring wells and

injection wells that are not in use will provide data on the generation of hydrocarbon vapor and flow of oxygen and ozone in the subsurface. Increased oxygen and ozone concentrations will be used to help determine the ROI. Monitoring will be performed utilizing an organic vapor monitor (OVM) for VOCs, a combustible gas meter for LEL/oxygen and a hand-held meter capable of detecting ozone at concentrations as low as 0.1 ppm.

The following procedure shall be performed to measure the vapor in the wells:

To measure the vapors trapped in the headspace of the well (i.e., the air space between the water level and the well cap), the well must not have been previously opened. The headspace measurement must be the first operation performed on the well; measurement of water level and collecting groundwater samples must follow, not precede, headspace vapor measurement. With the instrument fully warmed up and calibrated, the well cap is lifted on one side just far enough to insert the instrument's "sniffing" tube to its full length.

Note: The sampler should be certain that the tip of the tube does not contact the water level. As the instrument draws air and vapors out of the headspace, fresh air will be drawn in. Therefore, the concentration reading will rise rapidly as the vapors are first drawn into the instrument, then they will begin to fall as fresh air is drawn in. Record the maximum reading.

3.7 **Quality Assurance/Quality Control**

Quality Assurance/Quality Control (QA/QC) samples will be analyzed for parameters as shown in Table 3-3 by analytical methods presented in Table 3-2. QA/QC samples collected during this treatability study will include trip blanks, equipment rinsate samples, field blank samples, field duplicate samples, and matrix spike/matrix spike duplicates (MS/MSD).

3.7.1 Trip Blanks

Trip blank samples are required to accompany the samples submitted to the laboratory for VOC and TPH GRO analysis. Six trip blank samples are proposed as part of this treatability study, as shown on Table 3-3.

3.7.2 Equipment Rinsates

Equipment rinsate samples are collected from analyte-free water rinse of decontaminated equipment, which required decontamination and unused disposable equipment. Equipment rinsate blanks will be collected on a daily basis and submitted to a fixed-base analytical laboratory for analysis. The total number of equipment rinsate samples to be collected will be dependent on the length of the treatability study. The results from the blanks will be used to determine if the sampling equipment was free of contamination. The equipment rinsate samples are analyzed for the same parameters as the related samples. These samples will be associated with the subsurface soil and groundwater sampling equipment. These samples will be analyzed for the analytes presented in Table 3-3.

3.7.3 Field Blanks

Field blank samples consist of the source water used in equipment decontamination procedures. At a minimum, one field blank for each source of water must be collected and analyzed for the same parameters as the related samples. It is anticipated that two different sources of water (i.e., store-bought distilled water, and laboratory-grade de-ionized water) will be utilized for this treatability study as shown in Table 3-3.

3.7.4 Field Duplicates

Field duplicate samples of the subsurface soil and groundwater will be collected during the same time the corresponding environmental sample is collected. One duplicate sample will be collected at a frequency of 10 percent of environmental samples collected per media as shown on Table 3-1.

3.7.5 Matrix Spike/Matrix Spike Duplicates

MS/MSDs are laboratory derived and are collected to evaluate the matrix effect of the sample upon the analytical methodology. One MS/MSD will be collected for every 20 samples collected of a similar matrix as shown on Table 3-1.

3.8 Other Treatability Study Considerations

During the treatability study, the following activities will be performed.

- Site Clearing
- Utility Clearance
- Investigation Derived Waste (IDW) Management
- Decontamination
- Surveying

Each of these activities is discussed in the following sections.

3.8.1 Site Clearing

It may be necessary for site clearing to be performed so that the additional monitoring well may be installed.

3.8.2 Utility Clearance

The contractor conducting the implementation of this treatability study work plan will be responsible for clearing utilities for all proposed soil boring and well locations.

3.8.3 Investigation Derived Waste Management

Solid and liquid IDW will be generated during the treatability study. Solid IDW (i.e. soil cuttings) will be contained at the site in 55-gallon drums and staged onsite for proper disposal. Liquid IDW (e.g., development and purge water) will be contained in 55-gallon drums located at a designated location. All containers will be clearly labeled with the type of IDW contained, generation date, location, and the appropriate contact information.

Samples will be collected from both solid and liquid IDW storage containers and shipped to an off-site laboratory. The solid IDW sample will be a composite sample from all of the drums containing soil, while the liquid IDW sample will be a composite sample from all of the drums containing liquid. The solid IDW sample will be analyzed for toxicity characteristic leaching procedure (TCLP) VOCs, TCLP metals, TPH DRO/GRO, and reactivity, corrosivity, and ignitibility (RCI); while the aqueous IDW sample will be analyzed for BTEX, MtBE, and TPH DRO/GRO, as indicated on Table 3-3. The analytical results will be used to determine the type of disposal necessary for the soil and liquid

IDW (e.g., non-hazardous or hazardous). Soil, liquid, purge and/or decontamination water IDW will be shipped off-site in a timely manner to an approved disposal facility.

3.8.4 Decontamination

All reusable (non-dedicated and non-disposable) sampling and injection well installation equipment (i.e. augers, bits, split-spoon samplers, etc.), will be decontaminated between each sampling location following the procedures in accordance with the Final RCRA Facility Investigation Management Plans (Baker, 1995). The drill rig will be decontaminated before arriving at the site and before leaving the site. The remaining contaminant-free sampling equipment and materials utilized during this treatability study will be disposable.

3.8.5 Surveying

Injection well locations will be located by a surveyor in the field. Traditional survey equipment or a survey grade global positioning system (GPS) unit will be used to obtain vertical (+/- 0.01 foot) and horizontal (+/- 0.1 foot) locations and top of casing elevations for the wells for generating groundwater contours.

4.0 REPORTING

This section outlines the elements that will be included in the treatability study report. The treatability study report will include the following sections.

- Introduction
- Background
- Physical Characteristics of Study Area
- Treatability Study Activities
- Physical Results
- Analytical Results
- Conclusions and Recommendations
- References

The treatability study report sections are discussed in the following subsections.

4.1 Introduction

The introduction will provide a regulatory framework for NAPR and Site 1738, as well as a discussion of current conditions.

4.2 Background

The background will consist of a discussion of the past analytical results on groundwater samples obtained from the site.

4.3 Physical Characteristics of Study Area

This section will provide the environmental setting, including the regional and site-specific geology and hydrogeology. Regional and local climatic conditions that may be relevant to the results of the MtBE treatability study will also be discussed, as relevant.

4.4 MtBE Treatability Study Activities

This section will describe the activities performed during the course of the Site 1738 MtBE treatability study including a description of the equipment installed, chemicals used, sample locations, sample collection and handling procedures, QA/QC procedures, and analytical methods used. This section will also discuss any problems encountered including any deviations from the work plan and problem resolution.

4.5 **Physical Results**

This section will present the current site conditions at Site 1738 at the time of the MtBE treatability study. The site geology and hydrogeology, as ascertained during the treatability study will also be discussed. Additional information will include; drainage pathways, boring logs, vegetation, wetland boundaries, groundwater elevations, etc. The physical characteristics of the site will be recorded in the field. Those observations will be photographically recorded and summarized in this section.

4.6 Analytical Results

This section will present analytical results obtained during the course of the treatability study and an interpretation of the data to characterize the results of the addition of the chemical oxidation materials to the aquifer.

4.7 <u>Conclusions and Recommendations</u>

This section will compile the results and findings of the treatability study, both positive and negative. In addition, a justifiable recommendation on full-scale operation of the technology will be presented.

4.8 References

Source material used in the development of the treatability study report will be documented in the report's references section.

5.0 SCHEDULE

A schedule for the implementation of this work plan is provided as Figure 5-1.

It should be noted that this schedule is dependent upon regulatory approval time. Many other factors may extend the schedule such as equipment availability, weather delays, or unexpected system downtime.

6.0 PROJECT MANAGEMENT

An organizational chart presenting the proposed staffing for this project is provided on Figure 6-1. This section also outlines the responsibilities and reporting requirements of field personnel and staff.

6.1 Project Team Responsibilities

The Project Manager's responsibilities will be to direct the technical performance of the project staff, costs and schedule, ensuring that QA/QC procedures are followed during the course of the project. The Project Manager (to be determined) will maintain communication with the Navy BRAC PMO SE, Navy Technical Representative (NTR), Mr. Mark Davidson. Overall QA/QC for this project will be administered by a Sr. Technical Advisor.

The Site Manager (to be determined) will manage all field activities. The Site Manager's responsibilities include directing the field team and subcontractors. The Report Manager (to be determined) will direct the reporting effort associated with the field investigation, ensuring that all necessary staffing is utilized to assist in developing the Treatability Study Report for Site 1738.

The primary subcontractor for this work, GES, will be responsible for providing the patented treatment system used to inject oxygenating materials into the aquifer. GES will also provide on-site technical support during all phases of the treatability study including injection well and equipment installation

The Puerto Rico Analytical Laboratory has not been identified at this time. The laboratory will be responsible for performing analytical testing and reporting in accordance with this work plan.

6.2 Field Reporting Requirements

While in the field, GES will keep a daily log of activities performed. The daily logs will include all field measurements, sampling and analytical results, pressure readings, alarms and system upsets, and any other measurements taken to help assess system performance. The daily logs will be compiled by GES and submitted to the Navy weekly for review.

7.0 REFERENCES

Baker, 2011. Draft MtBE Investigation Report AOC F-Site 1738. Naval Activity Puerto Rico, Ceiba, Puerto Rico. January 14, 2011.

Baker, 2010. Draft Monitored Natural Attenuation Year 8 Quarter 2 Report. Naval Activity Puerto Rico, Ceiba, Puerto Rico. October 1, 2010.

Baker, 2008. Revised Final II Monitored Natural Attenuation Work Plan for AOC F. Naval Activity Puerto Rico, Ceiba, Puerto Rico. November 21, 2008.

Baker, 1995. Final RCRA Facility Investigation Management Plans, Naval Station Roosevelt Roads, Ceiba, Puerto Rico. Baker Environmental, Inc. September 14, 1995. Coraopolis, Pennsylvania.

Blasland, Bouck & Lee (BBL), Inc., 1999. Site Characterization for Site 1738. Naval Station Roosevelt Roads, Ceiba, Puerto Rico. February 28, 1999.

ITRC, 2001. Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater. June 2001.

United States Environmental Protection Agency (USEPA), 2007. RCRA § 7003 Administrative Order on Consent. Naval Activity Puerto Rico, formerly Naval Station Roosevelt Roads, Puerto Rico, EPA Docket No. RCRA-02-2007-7301. January 12, 2007.

Youngster, Laura K.G., 2009. Microbial Degradation of the Fuel Oxygenate Methyl TERT-Butyl Ether (MTBE). October 2009.

TABLE 1-1

GROUNDWATER QUALITY PARAMETERS - SITE 1738 AOC F MONITORED NATURAL ATTENUATION YEAR 8/QUARTER 2

NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Well ID/ Sample Date	Time	DTW (ft)	Vol. (ml)	Purge Rate (ml/min.)	Temp.	Sp. Cond. (mS/cm)	D.O. (ppm)	рН (S.U.)	ORP (mV)	Turb. (NTU)	Sample Description
	1341	16.10			30.12	2.307	8.48	6.68	-62.9	58.50	
	1346	16.12	850	170	30.08	2.455	5.15	6.70	-66.2	62.10	
	1351	16.14	1800	190	29.12	2.674	3.18	6.73	-70.2	75.50	
	1356	16.14	2700	180	29.06	2.691	1.30	6.75	-74.1	58.10	
_	1401	16.15	3550	170	29.48	2.695	1.08	6.76	-74.4	40.30	
1738MW01	1406	16.13	4450	180	29.21	2.701	1.12	6.77	-74.7	21.80	Clear, with
8/7/2010	1411	16.14	5300	170	29.10	2.700	0.83	6.76	-74.5	16.50	slight fuel odor.
8/ //2010	1416	16.13	6250	190	29.03	2.702	0.73	6.79	-74.5	12.20	stigitt fuel odol.
	1421	16.13	7200	190	28.87	2.704	0.72	6.80	-73.5	8.54	
	1426	16.13	8150	190	28.88	2.705	0.71	6.80	-73.9	8.40	
	1431	16.13	9050	180	28.86	2.708	0.70	6.81	-73.8	7.16	
	1436	16.13	10000	190	28.85	2.710	0.69	6.81	-73.5	7.08	
	1441	16.13	10900	180	28.84	2.712	0.68	6.81	-73.3	7.05	
	1110	15.18			30.64	2.755	5.95	6.53	17.0	20.40	
	1115	15.25	550	110	30.54	2.746	6.09	6.54	15.5	15.20	
	1120	15.56	1300	150	30.15	2.734	4.01	6.52	8.7	7.16	
	1125	15.94	2100	160	30.13	2.732	1.78	6.52	6.3	5.89	
	1130	16.06	3100	200	30.18	2.737	1.31	6.51	0.6	6.70	
	1135	16.15	4100	200	30.01	2.743	1.16	6.50	-2.4	8.15	
1738MW02	1140	16.05	5200	220	30.19	2.769	0.78	6.51	-6.5	7.16	Clear, with
8/7/2010	1145	16.08	6350	230	30.27	2.777	0.74	6.51	-9.9	6.80	slight odor.
	1150	16.08	7450	220	30.16	2.782	0.69	6.51	-11.2	5.61	S
	1155	16.08	8550	220	30.26	2.788	0.71	6.51	-12.3	4.85	
	1200	16.10	9650	220	30.05	2.786	0.70	6.51	-12.1	4.69	
l l	1205	16.09	10750	220	30.06	2.785	0.69	6.51	-11.9	4.61	
l l	1210	16.10	11850	220	30.05	2.784	0.68	6.51	-12.0	4.59	
l l	1215	16.10	12950	220	30.05	2.785	0.67	6.51	-11.9	4.57	
	0914	16.09			30.22	2.959	3.76	6.98	709.0	8.97	
ŀ	0919	16.51	1300	260	29.98	2.942	1.81	6.97	-70.0	25.00	
l l	0924	16.56	2700	280	29.89	2.948	1.78	6.95	-75.0	57.00	
ľ	0929	16.54	4000	260	30.09	2.951	1.67	6.93	-79.0	44.00	
	0934	16.52	5000	200	29.97	2.976	1.54	6.92	-80.0	27.00	Clear, with
1738MW03	0939	16.51	6000	200	29.89	2.964	1.36	6.91	-81.0	15.00	moderate fuel
	0944	16.50	7100	220	30.03	2.970	1.32	6.90	-83.0	10.00	
8/7/2010	0949	16.52	8100	200	30.08	2.971	1.44	6.89	-84.0	9.00	odor - possibly
	0954	16.52	9200	220	30.06	3.005	1.32	6.89	-86.0	10.50	gasoline.
	0959	16.53	10300	220	30.13	3.039	1.22	6.87	-87.0	6.70	
	1004	16.54	11300	200	30.17	3.081	1.19	6.86	-87.0	4.50	
	1009	16.54	12300	200	30.24	3.092	1.12	6.85	-88.0	4.20	
	1014	16.55	13300	200	30.28	3.095	1.10	6.86	-89.0	4.10	

TABLE 1-1

GROUNDWATER QUALITY PARAMETERS - SITE 1738 AOC F MONITORED NATURAL ATTENUATION YEAR 8/QUARTER 2

NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Well ID/ Sample Date	Time	DTW (ft)	Vol. (ml)	Purge Rate (ml/min.)	Temp.	Sp. Cond. (mS/cm)	D.O. (ppm)	pH (S.U.)	ORP (mV)	Turb. (NTU)	Sample Description
	1545	3.97			27.54	7.154	11.97	6.27	101.9	197.00	
	1550	4.30	800	160	27.45	7.248	9.62	6.26	104.0	212.00	
	1555	4.59	1600	160	27.47	7.351	5.60	6.30	105.0	184.00	
	1600	4.55	2400	160	27.43	7.345	2.85	6.32	104.4	153.00	
	1605	4.52	3200	160	27.35	7.314	2.27	6.34	104.1	72.50	
	1610	4.53	4000	160	27.30	7.257	1.74	6.36	102.7	57.40	
	1615	4.51	4800	160	27.20	7.231	1.70	6.36	102.8	51.50	
	1620	4.53	5600	160	27.21	7.216	1.85	6.36	101.7	55.90	
	1625	4.58	6400	160	27.20	7.217	1.80	6.39	100.1	56.40	
	1630	4.63	7200	160	27.23	7.254	1.07	6.43	103.0	53.00	
	1635	4.65	8000	160	27.15	7.240	0.73	6.42	99.5	48.30	
	1640	4.65	8800	160	27.09	7.233	0.71	6.42	99.8	41.50	
	1645	4.65	9600	160	27.15	7.223	0.69	6.42	100.0	41.00	
1738MW05R	1650	4.65	10400	160	27.16	7.234	0.69	6.46	101.5	39.90	Clear, with
8/7/2010	1655	4.66	11200	160	27.12	7.217	0.71	6.45	100.3	38.10	slight staining,
8/ //2010	1700	4.68	12000	160	27.09	7.209	0.66	6.45	99.6	33.90	no odor.
	1705	4.69	12800	160	27.08	7.197	0.67	6.45	99.5	29.60	
	1710	4.70	13600	160	27.04	7.187	0.59	6.45	98.3	28.90	
	1715	4.71	14400	160	27.01	7.174	0.62	6.45	97.2	28.50	
	1720	4.71	15200	160	27.03	7.163	0.62	6.45	96.0	26.90	
	1725	4.70	16000	160	27.02	7.155	0.59	6.46	93.9	25.50	
	1730	4.71	16800	160	27.01	7.151	0.59	6.46	94.1	25.10	
	1735	4.71	17600	160	26.97	7.138	0.55	6.46	93.2	23.80	
	1740	4.72	18400	160	26.97	7.133	0.60	6.46	92.5	23.90	
	1745	4.71	19200	160	26.95	7.118	0.57	6.46	91.4	24.20	
	1750	4.72	20000	160	26.94	7.107	0.55	6.46	91.3	21.30	
	1755	4.71	20800	160	26.93	7.108	0.55	6.46	91.2	20.90	
	1800	4.72	21600	160	26.94	7.107	0.54	6.46	90.9	21.10	
	1805	4.72	22400	160	26.94	7.108	0.55	6.46	90.9	20.90	

Notes:

DTW - Depth to water (measured from top of PVC casing)

ft - Feet

PVC - Polyvinyl chloride

Vol. - Volume purged in milliliters (ml)

ml/min. - Milliliters per minute

Temp. - Temperature in degrees centigrade (°C)

Sp. Cond. - Specific Conductance in milli-Siemens per centimeter (mS/cm)

D.O. - Dissolved Oxygen in parts per million (ppm)

pH - Standard Unit (S.U.)

ORP - Oxidation/Redution Potential in millivolts (mV)

Turb. - Turbidity in nephelometric turbidity units (NTU)

"--" - Reading not taken

TABLE 1-2

POSITIVE DETECTIONS OF NATURAL ATTENUATION PARAMETERS - SITE 1738 AOC F MONITORED NATURAL ATTENUATION YEAR 8/QUARTER 2 NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Si Samp	te ID 1738MW01 le ID 1738MW01-10B Date 8/7/2010	1738MW02 1738MW02-10B 8/7/2010	1738MW02D 1738MW02D-10B 8/7/2010	1738MW03 1738MW03-10B 8/7/2010	1738MW05R 1738MW05R-10B 8/7/2010							
Natural Attenuation Parameters (La	boratory Analysis)											
Methane (μg/L)	8.2	4.6 J	NA	78	0.098 J							
Dissolved Iron (μg/L)	1,640 J	2,780	NA	3,170 J	500 U							
Sulfate as SO4 (mg/L)	32.1	1,700	NA	3.04	384							
Natural Attenuation Parameters (Field Analysis)												
Dissolved oxygen (ppm)	< 1	< 1	NA	1.0	< 1							

Notes:

U - Not detected mg/L - milligram per liter μ g/L - microgram per liter NA - Not Analyzed

ppm - parts per million

TABLE 3-1

SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM - ENVIRONMENTAL SAMPLES AOC F SITE 1738

MtBE TREATABILITY STUDY WORK PLAN NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

			Fix	ed B	ase	Lab	orat	tory		Field Evaluation				
Sample Identification Number	Sample Depth (ft bgs)	MtBE	BTEX	TPH DRO/GRO	FOC	COD	Total and Diss. Iron	Carbon Dioxide	HPC	oa	Alkalinity	ORP	GW Elevations	Comment
Subsurface Soil Samples	•													
1738IW13-XX ⁽¹⁾	TBD	X	X	X	X									
1738IW13-XX ⁽¹⁾ D	TBD	X	X	X	X									Duplicate
1783IW13-XX ⁽¹⁾ MS/MSD	TBD	X	X	X	X									Matrix Spike/Matrix Spike Duplicate
1738IW14-XX ⁽¹⁾	TBD	X	X	X	X									
1738IW15-XX ⁽¹⁾	TBD	X	X	X	X									
1738IW16-XX ⁽¹⁾	TBD	X	X	X	X									
1738IW17-XX ⁽¹⁾	TBD	X	X	X	X									
1738MW18-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738MW18-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738MW19-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738MW19-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738MW20-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738MW20-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738SB106-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738SB106-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738SB107-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738SB107-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738SB108-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738SB108-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738SB108-XX ⁽¹⁾⁽²⁾ D	TBD	X	X	X										Duplicate
1738SB109-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
1738SB109-XX ⁽¹⁾⁽²⁾	TBD	X	X	X										
Baseline Groundwater Sam	ples													
1738GW01	NA	X	X	X		X		X		X	X	X	X	
1738GW01DD	NA	X	X	X										Duplicate
1738GW01MS	NA	X	X	X										Matrix Spike
1738GW01MSD	NA	X	X	X										Matrix Spike Duplicate
1738GW02	NA	X	X	X		X		X		X	X	X	X	
1738GW03	NA	X	X	X		X		X		X	X	X	X	
1738GW04	NA	X	X	X									X	
1738GW05	NA	X	X	X		X		X		X	X	X	X	
1738GW05R	NA	X	X	X		X		X	X	X	X	X	X	
1738GW05L	NA	X	X	X		X		X		X	X	X	X	
1738GW06	NA	X	X	X									X	

TABLE 3-1

SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM - ENVIRONMENTAL SAMPLES AOC F SITE 1738

MtBE TREATABILITY STUDY WORK PLAN NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

			Fix	ed B	Base	Lab	orat	tory		Field Evaluation				
Sample Identification Number	Sample Depth (ft bgs)	MtBE	BTEX	TPH DRO/GRO	FOC	COD	Total and Diss. Iron	Carbon Dioxide	НРС	DO	Alkalinity	ORP	GW Elevations	Comment
Baseline Groundwater Sam	ples (Conti	_	d)											
1738GW07	NA	X	X	X						X	X	X	X	
1738GW08	NA	X	X	X						X	X	X	X	
1738GW09	NA	X	X	X						X	X	X	X	
1738GW10	NA	X	X	X						X	X	X	X	
1738GW11	NA	X	X	X						X	X	X	X	
1738GW12	NA	X	X	X					X	X	X	X	X	
1738GW12D	NA	X	X	X										Duplicate
1738GW12MS	NA	X	X	X										Matrix Spike
1738GW12MSD	NA	X	X	X										Matrix Spike Duplicate
1738GW13S	Shallow	X	X	X			X			X	X	X	X	
1738GW13D	Deep	X	X	X			X			X	X	X	X	
1738GW14S	Shallow	X	X	X			X			X	X	X	X	
1738GW14D	Deep	X	X	X			X			X	X	X	X	
1738GW15S	Shallow	X	X	X			X			X	X	X	X	
1738GW15D	Deep	X	X	X			X			X	X	X	X	
1738GW16S	Shallow	X	X	X			X			X	X	X	X	
1738GW16D	Deep	X	X	X			X			X	X	X	X	
1738GW17S	Shallow	X	X	X			X			X	X	X	X	
1738GW17D	Deep	X	X	X			X			X	X	X	X	
1738GW17DD	Deep	X	X	X			X							Duplicate
1738GW18	NA	X	X	X		X	X	X		X	X	X	X	
1738GW19	NA	X	X	X						X	X	X	X	
1738GW20	NA	X	X	X						X	X	X	X	
1738GW21	NA	X	X	X						X	X	X	X	
1738GW22	NA	X	X	X						X	X	X	X	
Interim Groundwater Samp	oles													
1738GW01	NA	X	X	X										
1738GW01D	NA	X	X	X										Duplicate
1738GW01MS	NA	X	X	X										Matrix Spike
1738GW01MSD	NA	X	X	X										Matrix Spike Duplicate
1738GW02	NA	X	X	X										
1738GW03	NA	X	X	X										
1738GW05R	NA	X	X	X										
1738GW18	NA	X	X	X										

SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM - ENVIRONMENTAL SAMPLES AOC F SITE 1738

MtBE TREATABILITY STUDY WORK PLAN NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Sample Identification Number Numb				Fix	ed B	Base	Lab	orat	ory		Fiel	d Ev	alua	tion	
1738GW01	_	Depth	MtBE	BTEX	TPH DRO/GRO	FOC	COD	Total and Diss. Iron	Carbon Dioxide	НРС	DO	Alkalinity	ORP	GW Elevations	Comment
1738GW01D	Shutdown Groundwater Sar	mples		ır.	r	ı		r		ı		ı	1	r	
1738GW01MS							X		X		X	X	X	X	
1738GW01MSD	1738GW01D	NA													*
1738GW02	1738GW01MS	NA	X	X											
1738GW03	1738GW01MSD	NA	X	X	X										Matrix Spike Duplicate
1738GW04	1738GW02	NA	X				X		X		X	X	X	X	
1738GW05	1738GW03	NA	X	X	X		X		X		X	X	X	X	
1738GW05R	1738GW04	NA	X	X	X									X	
1738GW05L	1738GW05	NA	X	X	X		X		X		X	X	X	X	
1738GW06 NA X	1738GW05R	NA	X	X	X		X		X	X	X	X	X	X	
1738GW07	1738GW05L	NA	X	X	X		X		X		X	X	X	X	
1738GW08 NA X	1738GW06	NA	X	X	X									X	
1738GW09 NA X	1738GW07	NA	X	X	X						X	X	X	X	
1738GW10 NA X	1738GW08	NA	X	X	X						X	X	X	X	
1738GW11 NA X	1738GW09	NA	X	X	X						X	X	X	X	
1738GW12 NA X	1738GW10	NA	X	X	X						X	X	X	X	
1738GW12D NA X	1738GW11	NA	X	X	X						X	X	X	X	
1738GW12MS NA X <th< td=""><td>1738GW12</td><td>NA</td><td>X</td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td></td></th<>	1738GW12	NA	X	X	X					X	X	X	X	X	
1738GW12MSD NA X <t< td=""><td>1738GW12D</td><td>NA</td><td>X</td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>Duplicate</td></t<>	1738GW12D	NA	X	X	X										Duplicate
1738GW12MSD NA X <t< td=""><td>1738GW12MS</td><td>NA</td><td>X</td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>Matrix Spike</td></t<>	1738GW12MS	NA	X	X	X										Matrix Spike
1738GW13D Deep X <t< td=""><td>1738GW12MSD</td><td>NA</td><td>X</td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	1738GW12MSD	NA	X	X	X										
1738GW14S Shallow X	1738GW13S	Shallow	X	X	X			X			X	X	X	X	*
1738GW14S Shallow X	1738GW13D	Deep	X	X	X			X			X	X	X	X	
1738GW14D Deep X <t< td=""><td>1738GW14S</td><td></td><td>X</td><td>X</td><td>X</td><td></td><td></td><td>X</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td></td></t<>	1738GW14S		X	X	X			X			X	X	X	X	
1738GW15S Shallow X		Deep													
1738GW15D Deep X <t< td=""><td></td><td>-</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>		-													
1738GW16S Shallow X											_				
1738GW16D Deep X <t< td=""><td></td><td>-</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>		-													
1738GW17S Shallow X											_				
1738GW17D Deep X <t< td=""><td></td><td>-</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>		-													
1738GW17DD Deep X X X X X Duplicate 1738GW18 NA X															
1738GW18 NA X X X X X X X X X X X X X X X X X X		1											-	1 -	Duplicate
1738GW19 NA X X X X X X X		-					X		X		X	X	X	X	
1738GW20 NA X X X X X X X X X															

SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM - ENVIRONMENTAL SAMPLES AOC F SITE 1738

MtBE TREATABILITY STUDY WORK PLAN NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

			Fix	ed B	Base	Lab	orat	tory		Fiel	d Ev	alua	tion	
Sample Identification Number	Sample Depth (ft bgs)	MtBE	BTEX	TPH DRO/GRO	FOC	COD	Total and Diss. Iron	Carbon Dioxide	HPC	ОО	Alkalinity	ORP	GW Elevations	Comment
Shutdown Groundwater Sar	mples (Con	tinu	ied)											
1738GW21	NA	X	X	X						X	X	X	X	
1738GW22	NA	X	X	X						X	X	X	X	
Post Shutdown Groundwate	er Samples													
1738GW01	NA	X	X	X										
1738GW01D	NA	X	X	X										Duplicate
1738GW01MS	NA	X	X	X										Matrix Spike
1738GW01MSD	NA	X	X	X										Matrix Spike Duplicate
1738GW02	NA	X	X	X										
1738GW03	NA	X	X	X										
1738GW04	NA	X	X	X										
1738GW05	NA	X	X	X										
1738GW05R	NA	X	X	X										
1738GW05L	NA	X	X	X										
1738GW06	NA	X	X	X										
1738GW07	NA	X	X	X										
1738GW08	NA	X	X	X										
1738GW09	NA	X	X	X										
1738GW10	NA	X	X	X										
1738GW11	NA	X	X	X										
1738GW12	NA	X	X	X										
1738GW12D	NA	X	X	X										Duplicate
1738GW12MS	NA	X	X	X										Matrix Spike
1738GW12MSD	NA	X	X	X										Matrix Spike Duplicate
1738GW13S	Shallow	X	X	X										*
1738GW13D	Deep	X	X	X										
1738GW14S	Shallow	X	X	X										
1738GW14D	Deep	X	X	X										
1738GW15S	Shallow	X	X	X										
1738GW15D	Deep	X	X	X										
1738GW16S	Shallow	X	X	X										
1738GW16D	Deep	X	X	X										
1738GW17S	Shallow	X	X	X										
1738GW17D	Deep	X	X	X										
1738GW17DD	Deep	X	X	X										Duplicate

SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM - ENVIRONMENTAL SAMPLES AOC F SITE 1738

MtBE TREATABILITY STUDY WORK PLAN NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

		Fixed Base Laboratory Field Evaluation												
Sample Identification Number	Sample Depth (ft bgs)	MtBE	BTEX	TPH DRO/GRO	FOC	COD	Total and Diss. Iron	Carbon Dioxide	HPC	oa	Alkalinity	ORP	GW Elevations	Comment
Post Shutdown Groundwate	r Samples	(Co	ntin	ued))									
1738GW18	NA	X	X	X										
1738GW19	NA	X	X	X										
1738GW20	NA	X	X	X										
1738GW21	NA	X	X	X										
1738GW22	NA	X	X	X										

Notes:

- (1) XX-The designation for the depth interval from which the sample will be collected (i.e., 01=1 to 3 feet bgs; 02=3 to 5 feet bgs; etc).
- (2) Two subsurface samples will be collected: one just above the groundwater table and one at a depth to be established in the field.

ft bgs - feet below ground surface

NA - Not Applicable

TBD - To be determined in the field

BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

TPH - Total Petroleum Hydrocarbons

DRO - Diesel Range Organics

GRO - Gasoline Range Organics

MtBE - Methyl tertiary-Butyl Ether

FOC - Fraction of Organic Carbon

COD - Chemical Oxygen Demand

DO - Dissolved Oxygen

ORP - Oxidation-Reduction Potential

ISCO - In-Situ Chemical Oxidation

GW - Groundwater

HPC - Heterotrophic Plate Count

Diss. - Dissolved

METHOD PERFORMANCE LIMITS APPENDIX IX COMPOUND LIST AND CONTRACT REQUIRED QUANTITATION LIMITS (CRQL) AOC F SITE 1738

MtBE TREATABILITY STUDY WORK PLAN NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

	Quantitati	on Limits*		Preparatio	n Methods	
	Water	Low Soil	Analytical			Method
Volatiles	(µg/L)	(µg/kg)	Method	Water	Soil	Description
Benzene	0.5	5.0	8260B	5030B	5035	GC/MS
Ethyl benzene	0.5	5.0	8260B	5030B	5035	GC/MS
Methyl tertiary-butyl ether (MtBE)	0.5	5.0	8260B	5030B	5035	GC/MS
Toluene	0.5	5.0	8260B	5030B	5035	GC/MS
Xylene	0.5	10	8260B	5030B	5035	GC/MS
	Quantitati	on Limits*		Preparatio	n Methods	
Total Petroleum	Water	Low Soil	Analytical			Method
Hydrocarbons	(mg/L)	(mg/kg)	Method	Water	Soil	Description
TPH DRO	0.5	0.5	8015C	3520C	3550B	GC
TPH GRO	0.5	10	8015C	5030B	5035	GC
	Quantitati	on Limits*		Preparatio	n Methods	
	Water	Soil	Analytical			Method
GES Requested Parameters	(µg/L)	(µg/kg)	Method	Water	Soil	Description
Total and Dissolved Iron	50	NA	6010B	3005A/3010A	NA	ICP-AES
						Closed Reflux and
Chemical Oxygen Demand	20000	NA	5220D	5220D	NA	Colorimetric
G. I. Bi ii		37.4	G) (2220D	G) (2220D	27.4	Determination
Carbon Dioxide	5 Colony	NA	SM 2320B	SM 2320B	NA	Titrametric
Heterotrophic Plate Count	Count per	NA	SM 9215	SM 9215	NA	Pour Plate
l late Count	Volume	IVA	SIVI 9213	SIVI 9213	IVA	1 our 1 rate
Fraction of Organic Carbon	NA	0.003**	EPA 9060	NA	EPA 9060	_
		on Limits*		Preparatio		
	Water	Soil	Analytical	•		Method
TCLP Volatiles	(µg/L)	(µg/L)	Method	Water	Soil	Description
Benzene	NA	5	8260B	NA	1311/5030B	GC/MS
Carbon tetrachloride	NA	5	8260B	NA	1311/5030B	GC/MS
Chlorobenzene	NA	5	8260B	NA	1311/5030B	GC/MS
Chloroform	NA	5	8260B	NA	1311/5030B	GC/MS
1,2-Dichloroethane	NA	5	8260B	NA	1311/5030B	GC/MS
1,1-Dichloroethene	NA	5	8260B	NA	1311/5030B	GC/MS
2-Butanone (MEK)	NA	12	8260B	NA	1311/5030B	GC/MS
Tetrachloroethene	NA	5	8260B	NA	1311/5030B	GC/MS
Trichloroethene	NA	5	8260B	NA	1311/5030B	GC/MS
Vinyl chloride	NA	5	8260B	NA	1311/5030B	GC/MS

METHOD PERFORMANCE LIMITS APPENDIX IX COMPOUND LIST AND CONTRACT REQUIRED QUANTITATION LIMITS (CRQL) AOC F SITE 1738

MtBE TREATABILITY STUDY WORK PLAN NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

	Quantitati	ion Limits*		Preparation	on Methods	
TCLP Metals	Water (µg/L)	Soil (µg/L)	Analytical Method	Water	Soil	Method Description
Arsenic	NA	10.0	6010C	NA	1311/3010A	ICP
Barium	NA	200.0	6010C	NA	1311/3010A	ICP
Cadmium	NA	5.00	6010C	NA	1311/3010A	ICP
Chromium	NA	10.0	6010C	NA	1311/3010A	ICP
Lead	NA	10.0	6010C	NA	1311/3010A	ICP
Selenium	NA	10.0	6010C	NA	1311/3010A	ICP
Silver	NA	5.0	6010C	NA	1311/3010A	ICP
	Quantitati	ion Limits*		Preparati	on Methods	
Reactivity, Corrosivity,	Water	Low Soil	Analytical			Method
Ignitability	(mg/L)	(mg/kg)	Method	Water	Soil	Description
Reactive Cyanide	250	125	9014	9012A	9012A	Titrimetric
Flashpoint/Ignitability	NA	NA	1030	NA	NA	Pensky-Martens Closed Cup Tester
pH (s.u.)	NA	NA	9045D	NA	NA	Electrometric
Reactive Sulfide	250	125	9034	NA	9030B	Titrimetric

Notes:

* Quantitation limits listed for soil are based on wet weight. The quantitation limits calculated

by the laboratory for soil/sediment, calculated on dry weight basis, will be higher.

** Dimensionless

μg/L - micrograms per liter

μg/kg - micrograms per kilogram

mg/kg - milligrams per kilogram

mg/L - milligrams per liter

NA - not applicable

GC - Gas Chromotography

GC/MS - Gas Chromotography/Mass Spectrometry

ICP - Inductively Coupled Plasma

ICP-AES - Inductively Coupled Plasma - Atomic Emission Spectroscopy

TCLP - Toxicity Characteristic Leaching Procedure

SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM - QA/QC SAMPLES AOC F SITE 1738

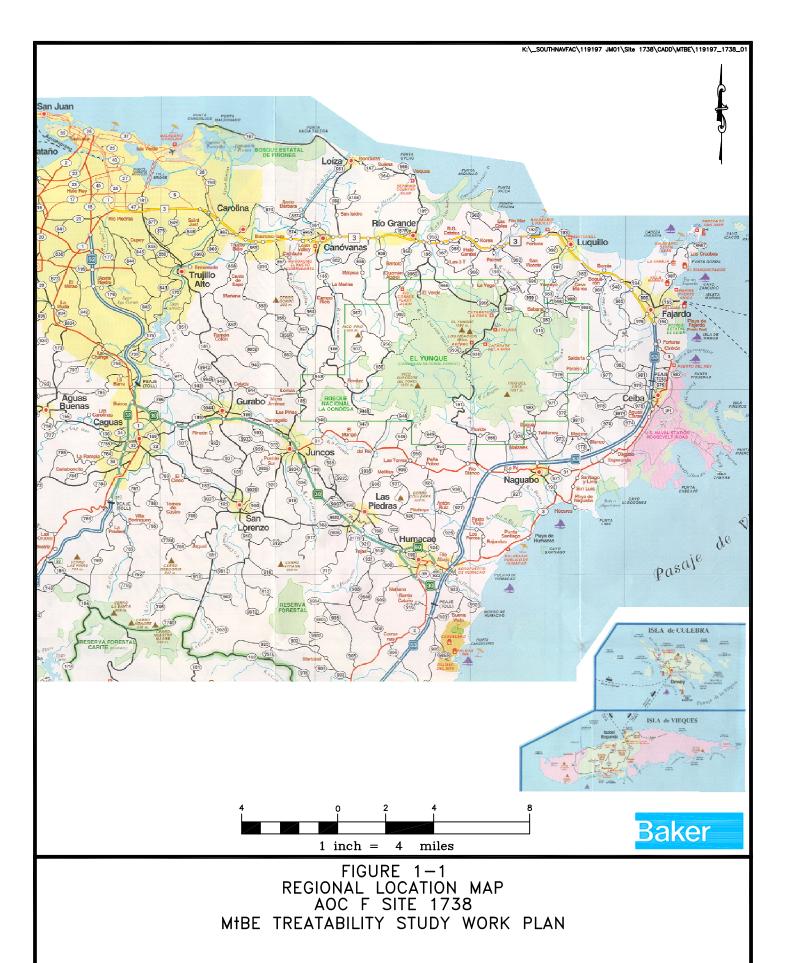
MtBE TREATABILITY STUDY WORK PLAN NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

	Aq	jueous S R	Sample equesto	-	ysis	Soli	id Sam _j Req	ples An uested	nalysis	
Media	MtBE	BTEX	TPH DRO (8015)	TPH GRO (8015)	Total and Dissolved Iron	TCLP Volatiles	TCLP Metals	TPH DRO/GRO	Reactivity, Corrosivity, Ignitability	Comment
Trip Blank Sar					1	ı	ı			
1738TB04	X	X		X						
1738TB05	X	X		X						
1738TB06	X	X		X						
1738TB07	X	X		X						
1738TB08	X	X		X						
1738TB09	X	X		X						
Equipment Ri					per day	of field	l work	T		
1738ER09	X	X	X	X						Macro Core Liner
1738ER10	X	X	X	X						Macro Core Liner
1738ER11	X	X	X	X						Macro Core Liner
1738ER12	X	X	X	X	X					Groundwater Sampling Equipment
1738ER13	X	X	X	X	X					Groundwater Sampling Equipment
1738ER14	X	X	X	X	X					Groundwater Sampling Equipment
1738ER15	X	X	X	X	X					Groundwater Sampling Equipment
1738ER16	X	X	X	X	X					Groundwater Sampling Equipment
1738ER17	X	X	X	X	X					Groundwater Sampling Equipment
Field Blank Sa	mples									
1738FB03	X	X	X	X						Lab Grade Deionized Water
1738FB04	X	X	X	X						Store Bought Distilled Water
IDW Samples										
1738IDW03	X	X	X	X						Aqueous
1738IDW04						X	X	X	X	Solid

Notes:

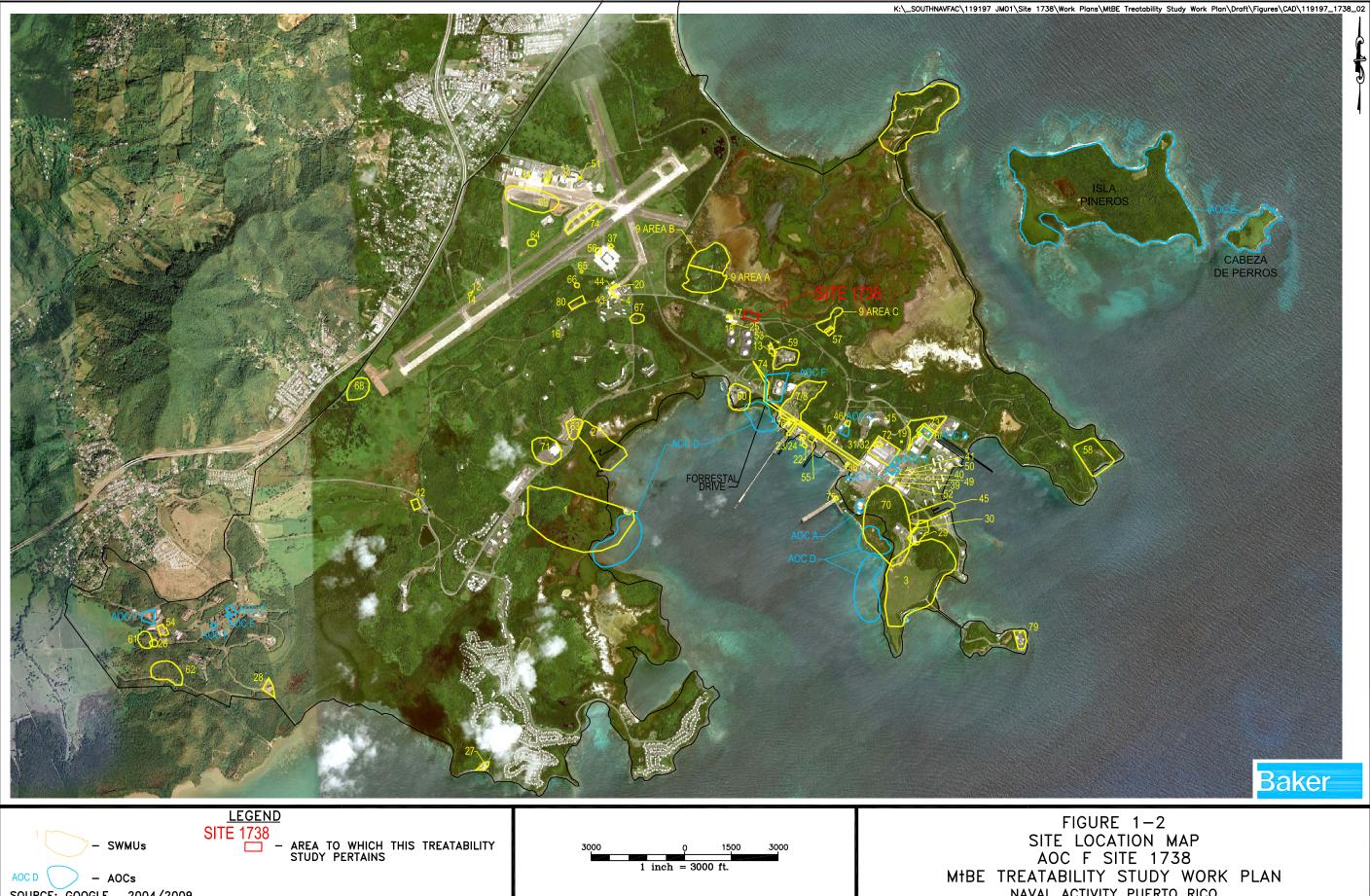
- BTEX Benzene, Toluene, Ethylbenzene, Xylenes
- TPH Total Petroleum Hydrocarbons
- DRO Diesel Range Organics
- GRO Gasoline Range Organics
- MtBE Methyl tertiary-Butyl Ether
- QA/QC Quality Assurance/Quality Control
- IDW Investigation Derived Waste





NAVAL ACTIVITY PUERTO RICO PUERTO RICO

SOURCE: METRODATA, INC., 1999.





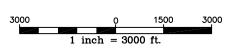


FIGURE 1-2 SITE LOCATION MAP AOC F SITE 1738 MtBE TREATABILITY STUDY WORK PLAN NAVAL ACTIVITY PUERTO RICO

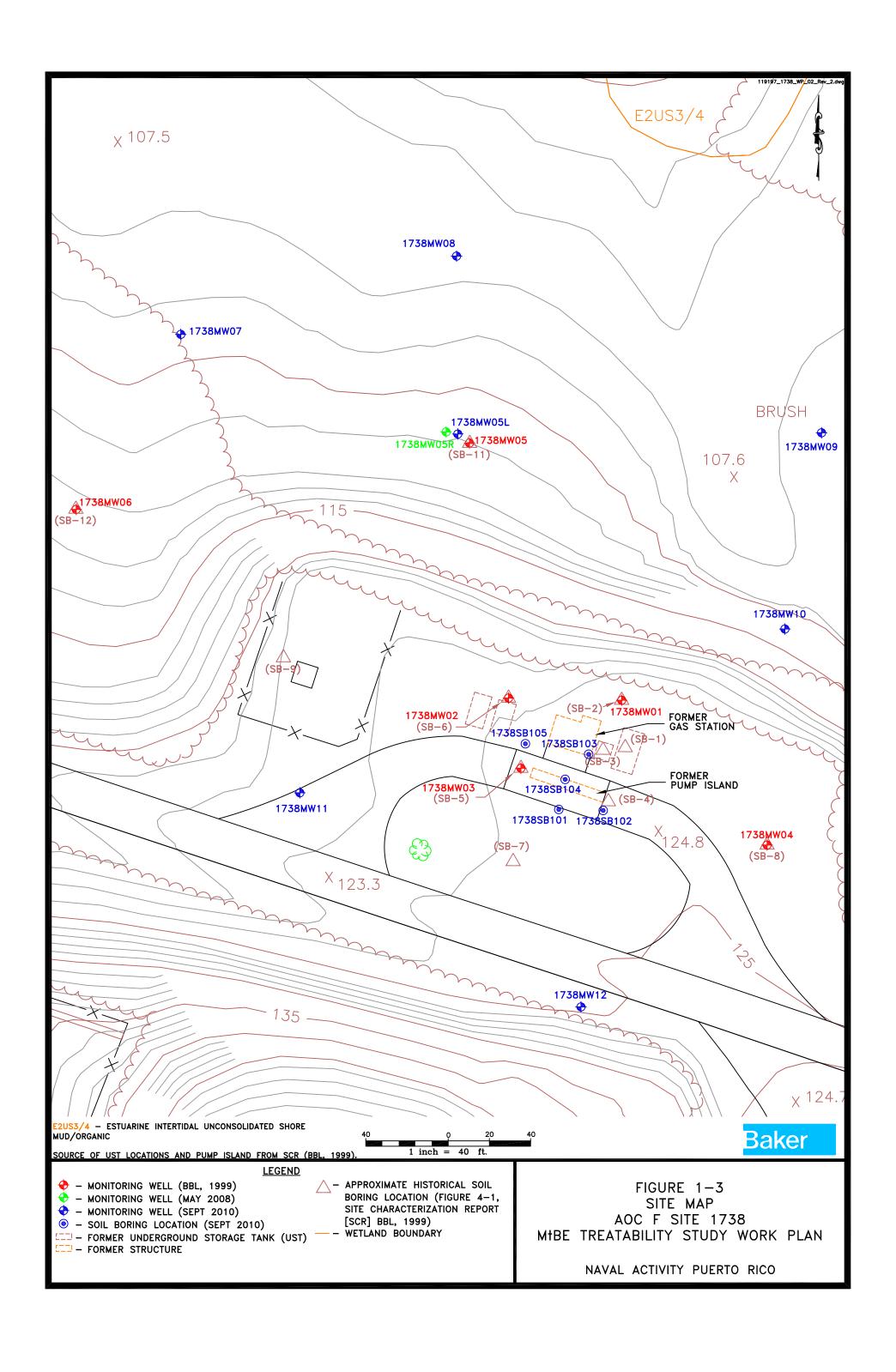
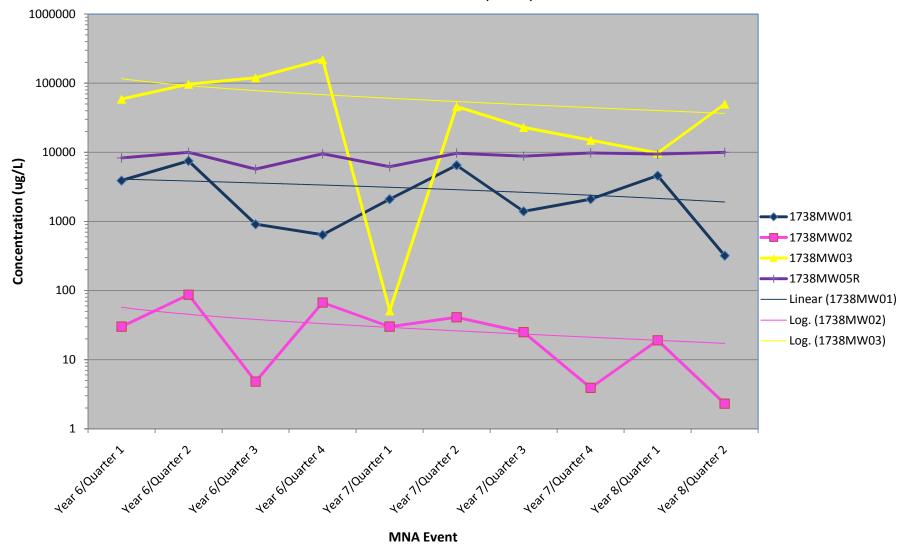
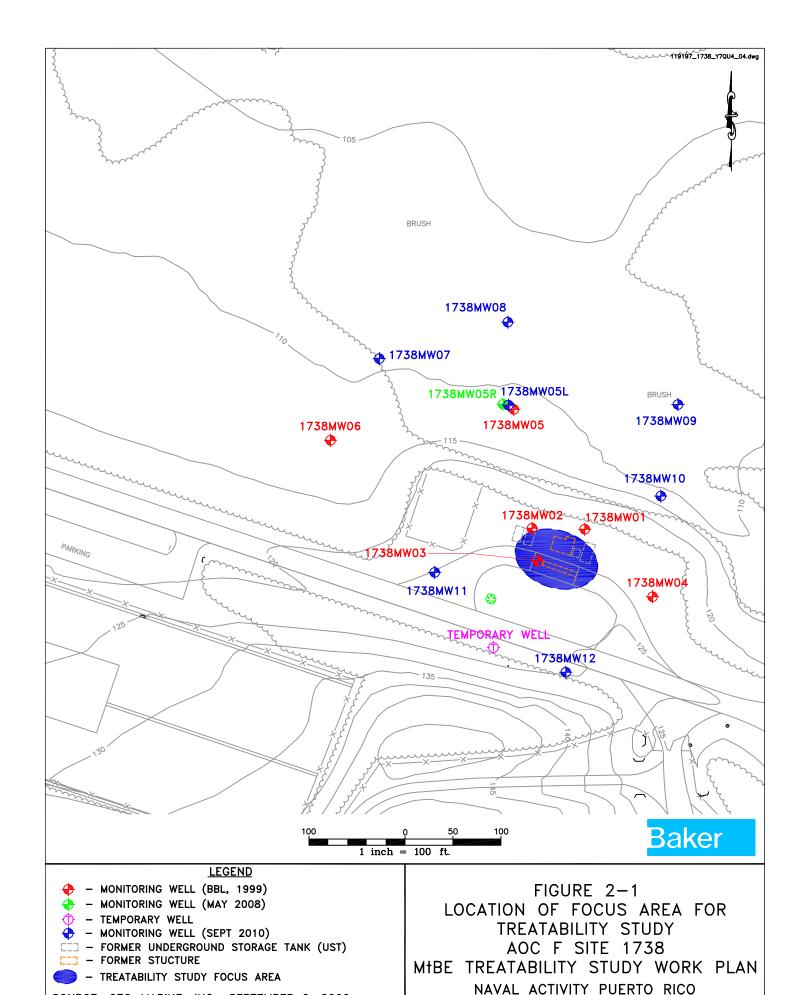
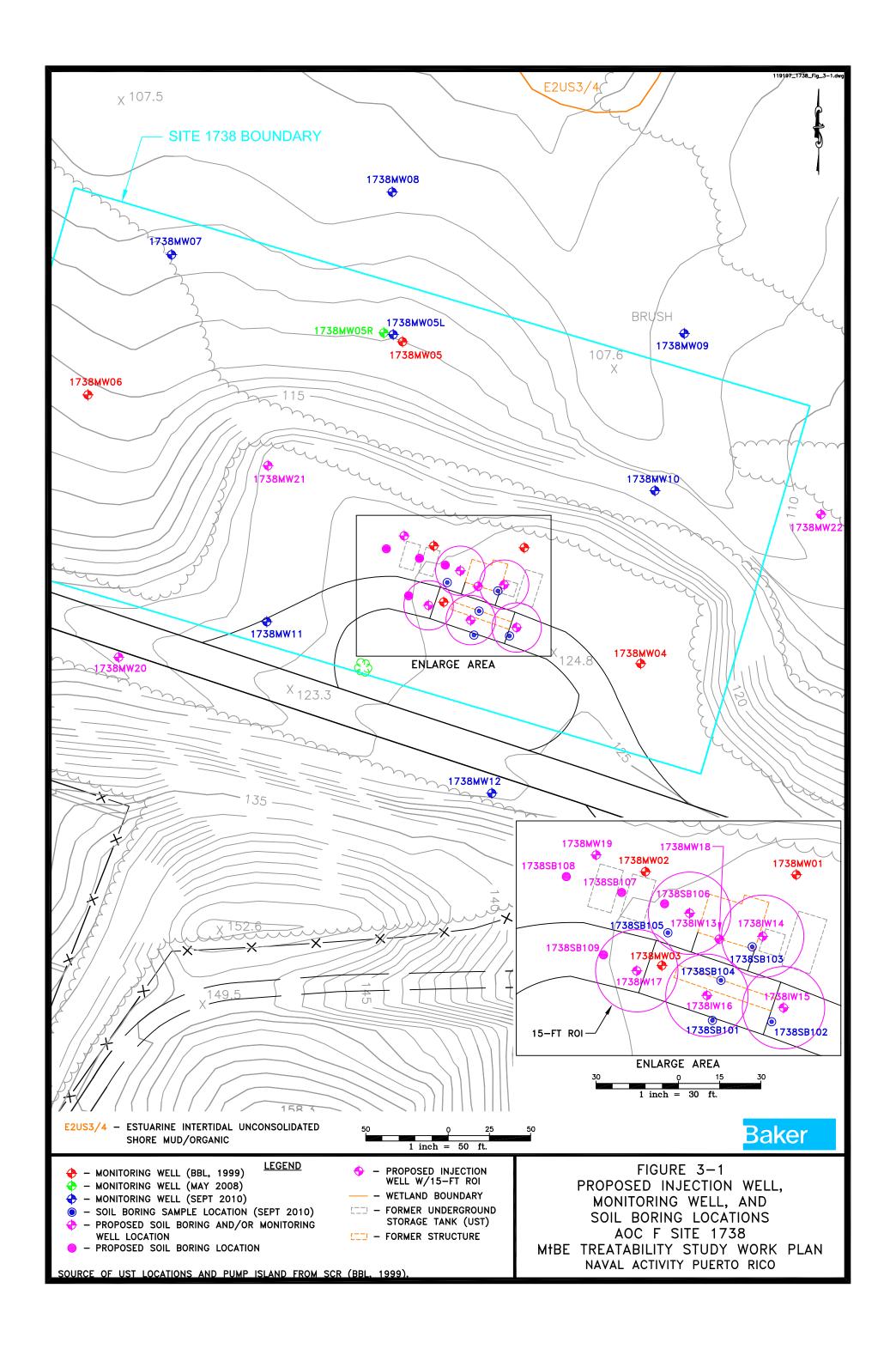


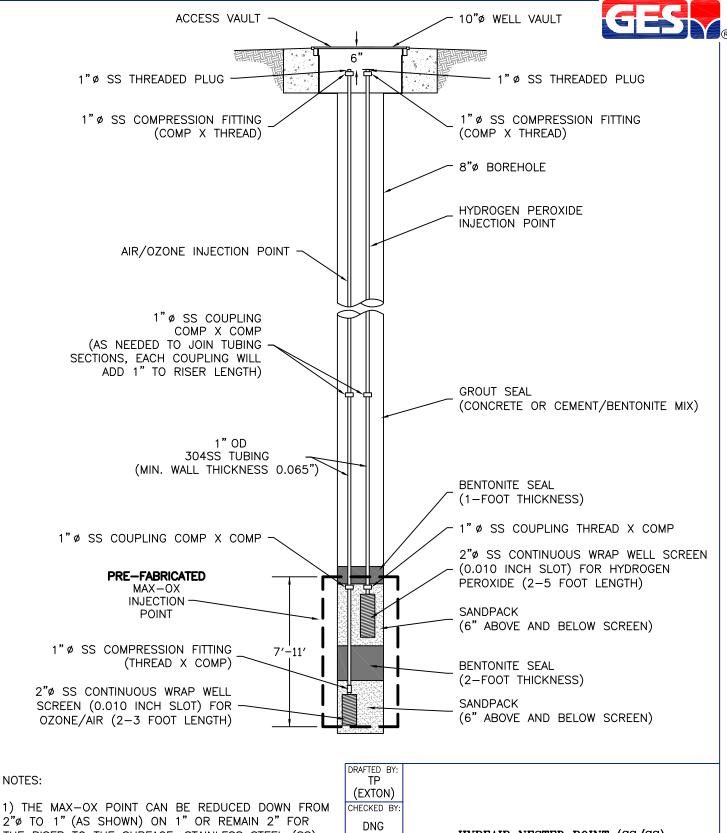
FIGURE 1-4
MtBE CONCENTRATIONS VS. MNA EVENT
AOC F SITE 1738
MtBE TREATABILITY STUDY WORK PLAN
NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO





SOURCE: GEO-MARINE, INC., SEPTEMBER 6, 2000.





- 1) THE MAX-OX POINT CAN BE REDUCED DOWN FROM 2"Ø TO 1" (AS SHOWN) ON 1" OR REMAIN 2" FOR THE RISER TO THE SURFACE. STAINLESS STEEL (SS) PIPE MAY BE USED IN PLACE OF TUBING FOR 1" OR 2"Ø RISERS.
- 2) INFORMATION CONTAINED WITHIN THIS DRAWING IS PROPRIETARY AND CONFIDENTIAL. ANY COPYING, DISTRIBUTION, OR DISSEMINATION WITHOUT THE CONSENT OF GROUNDWATER & ENVIRONMENTAL SERVICES, INC. IS PROHIBITED.

TP (EXTON)			
CHECKED BY:			
DNG	HYPEAIR NESTE	n doint (cc/c	<i>a)</i>
REVIEWED BY:	nifeair nesie	n Louid (paya	<i>ა)</i>
CBW			
	Groundwater & Environment	onmental Servi	ices, Inc.
	440 CREAMERY WAY, SUI	TE 500, EXTON,	PA 19341
	NOT TO SCALE	DATE	FIGURE
		06-13-08	

FIGURE 5-1 PROPOSED PROJECT SCHEDULE AOC F SITE 1738

MtBE TREATABILITY STUDY WORK PLAN NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

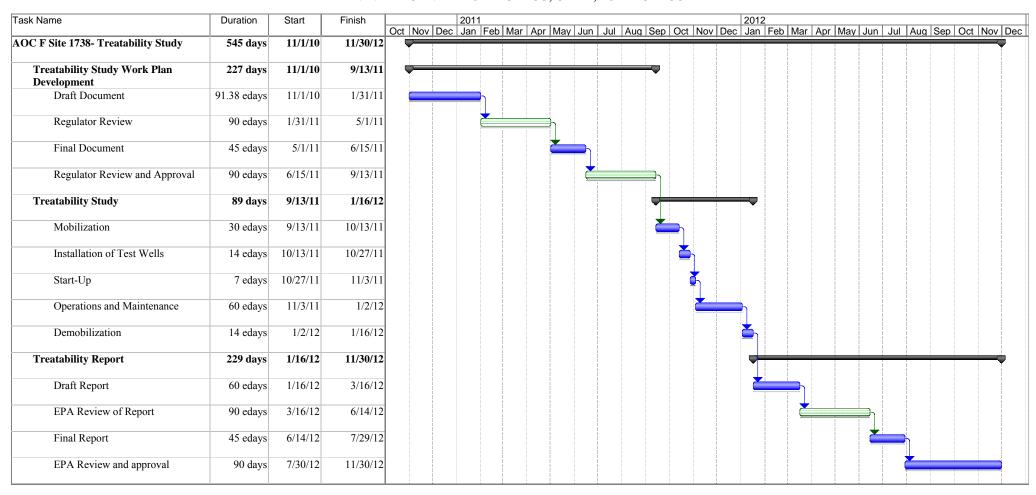
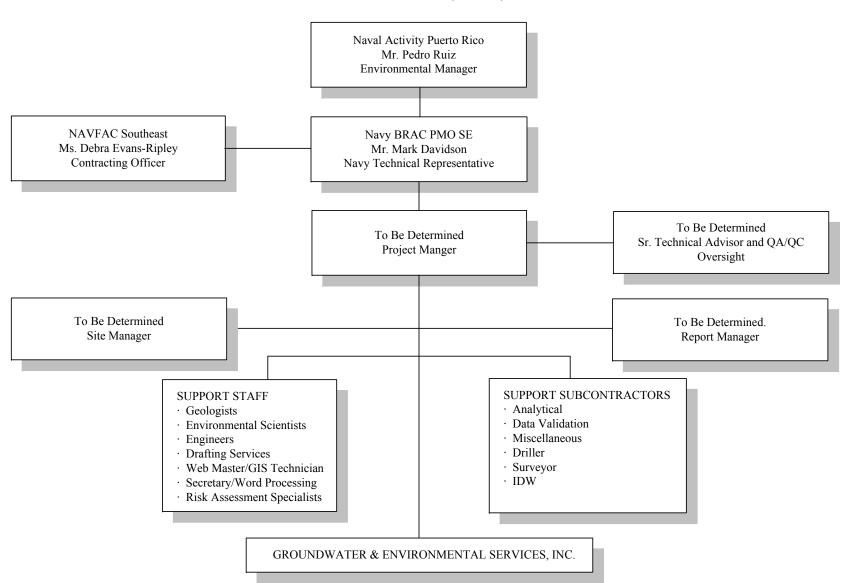


FIGURE 6-1 PROJECT ORGANIZATION TREATABILITY STUDY WORK PLAN – SITE 1738 NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO





APPENDIX A

IN-SITU CHEMICAL OXIDATION DESIGN PARAMETERS AOC F SITE 1738 MtBE TREATABILITY STUDY WORK PLAN NAVAL ACTIVITY PUERTO RICO, CEIBA, PUERTO RICO

Site ID Sample ID Sample Date	1738SB05R 1738GW05R 9/20/2010	1738SB12 1738GW12 9/20/2010
Depth		
Total Inorganics (µg/L)		
Iron	649 J	500 UJ
Manganese	580 J	583 J
Dissolved Inorganics (µg/L)		
Manganese	554 J	564 J
Conventionals (mg/L)		
Chemical Oxygen Demand	96	64
Nitrate (as N)	0.34	0.67

Qualifiers/Notes:

UJ - Reported quantitation limit is qualified as estimated

J - The analyte was positively identified; the quantitation is an estimation

μg/L - micrograms per liter

mg/L - milligrams per liter

mg/kg - milligrams per kilogram

EMSL Analytical, Inc.

5125 Adanson Street, Suite 900 Orlando, Florida 32804 (407)599-5887 Fax (407)599-9063

	Report	Date:	10/4/2010
--	--------	-------	-----------

Client: Compuchem Environmental Corp

5001 Madison Avenue

Cary, NC 17513

Attn: Cathy Dover

Project: Side 1738 M+BE

EMSL Ref. Number: 341007619

Date and Time Test Begin _9/23/10 2:30 PM_____

Date and Time Test Ended 10/4/10 2:30 PM

Heterotrophic plate count ID (HPC-SM 9215b) M016

Sample	Location	Bacteria ID	Counts
1	1738GW05R	Actinobacillus	450
2	1738GW12	Brevundimonas vesicularis	5000
		Ralstonia	13000
		Pseudomonas Resinovorans	28000
		Pseudomonas aeruginosa	2000
		Pasturella	700000

Analysis Performed By:	Dr. Blanca Cortes	10/4/10
	Analyst	Date
Approved EMSL Signatory:		
	Dr. Blanca Cortes	Date

APPENDIX B SUCCESS STORIES USING CHEMICAL OXIDATION TECHNOLOGY



HypeAir-EX Case Study: Active Retail Station

Hydrogen peroxide, ozone, oxygen, and air injection system for remediation of dissolved- and adsorbed-phase petroleum impact in sandy soil

A HypeAir-Ex system was used at an active retail site to remediate adsorbed-phase hydrocarbon impact

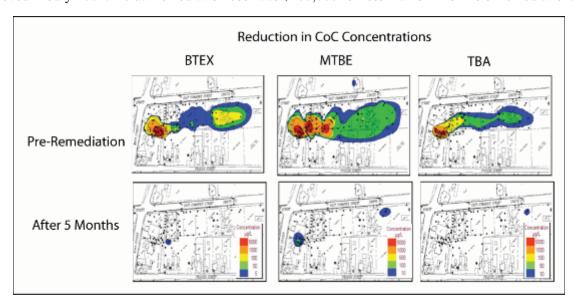
and an 800-foot plume of dissolved-phase BTEX, MTBE, TAME, and TBA. The site was in an area of sandy soil with depth to water of eight to ten feet. Feasibility testing showed that ozone could effectively be distributed into the subsurface (15 to 25 ft ROI observed during tests). A life cycle cost analysis modeled remedial technologies to evaluate alternative approaches. Chemical oxidation was projected as the most effective solution at \$320,000 for 12 months of remediation.



A HypeAir-EX system was designed to operate continuously for up to nine months. The system control panel cycled injections of ozone, hydrogen peroxide, oxygen, and air to nested stainless steel injection wells. A vapor recovery system was used to prevent the accumulation of vapors in the vadose zone and help remediate an unsaturated adsorbed-phase mass near an existing UST system.

Dissolved oxygen concentrations in groundwater, below 2 mg/L throughout the plume prior to remediation, were noted at up to 25 mg/L at injection wells and 20 mg/L at nearby observation wells. After three months of remediation, only three on-site sampling locations indicated detectable concentrations of BTEX. After five months of remediation, BTEX was not detected in any sampling location. Only one well indicated MTBE concentrations greater than 60 μ g/L, and only one well indicated TBA concentrations greater than 50 μ g/L. After seven months, DNREC granted approval to deactivate the remediation systems and initiate one year of groundwater monitoring for closure.

BTEX was not detected in any of the 11 sampling locations after one-quarter of monitoring. Only one well showed MTBE concentrations above 30 μ g/L, and all wells indicated TBA concentrations of less than 50 μ g/L. After three quarters of monitoring, only one well, located in the original source area, indicated MTBE concentrations above 30 μ g/L. Concentrations of BTEX, MTBE, and TBA were ND or less than 4 μ g/L in the other eight compliance sampling locations. No Further Action designation was achieved in July 2004. Actual remediation cost was \$200,000 for less than six months of remediation.



ISCO at Site with Challenging Geologic Conditions

Diving MTBE plume in heterogeneous soil matrix

Location: Connecticut

Type of Site: retail service station and off-site

residential property

Constituent(s) of Concern: benzene (primary);

MTBE (secondary)

COC	Max. Concentration in Groundwater (µg/L)
Benzene	15,600
MTBE	270,000

Media of Concern: groundwater

Lithology: silty sand and silty clay with gravel stringers

Remediation Methods:

in-situ chemical oxidation (ISCO) using ozone, hydrogen peroxide, and sodium persulfate

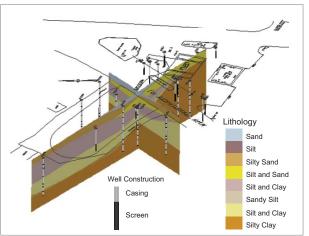
Effectiveness:

COC	Cleanup Criteria	Avg. Concentration (μg/L)	
COC		Pre-Treatment	Post-Treatment
Benzene	130	415	15
MTBE	21,000	13,282	1,755

Background

The Max-Ox Group was retained to develop a remedial strategy for regulatory closure of a retail petroleum release site in Connecticut. The site is located in a "GA" aquifer in a residential area; this groundwater classification is the drinking water protection standard. Concentrations of volatile organic compounds (VOCs) in groundwater must meet both drinking water standards and residential volatilization criteria. Sensitive receptors downgradient of the site include a stream, a river, and residential properties with basements. Adjacent residential properties include two with operating non-potable wells.

Soils consist of silty sand with clayey silts interbedded with fine sand and gravel. The estimated porosity is 0.33, the hydraulic conductivity (Kh) is approximately 0.26 ft/day, and the groundwater velocity ranges from 5.3 to 26.9 feet per year. The strong groundwater gradient is approximately 0.02 to 0.09 ft/ft and the downward vertical gradient as much as 1.5 ft/ft. This resulted in a VOC plume extending from 10 to 80 feet below ground surface (bgs).



Site Lithology and Well Construction

Primary constituents of concern (COCs) were benzene and the oxygenate methyl tertiary-butyl ether (MTBE). Groundwater concentrations exceeded the drinking water standard and residential volatilization criteria. The core of the dissolved phase plume extended from 10 to 80 feet bgs and measured 250 feet long by 130 feet wide, with the full extent greater than 400 feet long.

The highly heterogeneous geology precluded the use of conventional remedial technologies such as air sparging or total phase extraction.

HypeAir Pilot Test

An in-situ chemical oxidation (ISCO) pilot test was conducted using the patented HypeAir® injection process. Test results were used to determine the appropriate injection well spacing for site-wide ISCO application.

Three drums of hydrogen peroxide were injected in the initial test. The results were unfavorable, indicating that ISCO may not be the appropriate remedial solution. A review of pilot test data indicated that the injection wells had silted due to the fine soil matrix and off-gassing of the hydrogen peroxide, which created significant pressure limiting the injection flow rates. The Max-Ox Group designed and installed wells specifically for the chemical oxidizer injection. A second pilot test showed favorable results with good dispersal of hydrogen peroxide and even distribution of dissolved oxygen within the treatment zone.

ISCO Treatment

A full-scale ISCO remedy was designed based on the pilot test data. The strategy called for three to five three-week injection events to be performed over a two-year period. A total of 32 injection wells were installed throughout the dissolved-phase plume. For each event, hydrogen peroxide, ozone, and sodium persulfate

ISCO at Site with Challenging Geologic Conditions

Diving MTBE plume in heterogeneous soil matrix

were injected to enhance chemical oxidation reactions. Hydrogen peroxide was injected at a rate of 0.5 gpm into each point, with simultaneous injection into at least three wells to increase efficacy. Ozone was injected continuously during the work at 2 pounds per day or more. Well development was conducted before each injection event and throughout the work to ensure that injection rates could be maintained.

Following each injection event, groundwater samples were collected to evaluate effectiveness and optimize subsequent events. A review of the post-injection groundwater data from the second event revealed that a significant mass of hydrocarbons was present beneath the state highway and downgradient from the station. Impacted groundwater from this region was migrating







injecting persulfate into angled well

onto the downgradient residential properties and contributing to elevated COC concentrations. Based on a revised conceptual site model and the results of previous injection results, it was determined that three additional injection wells were required to address this new "hot spot".

Angled Injection Wells

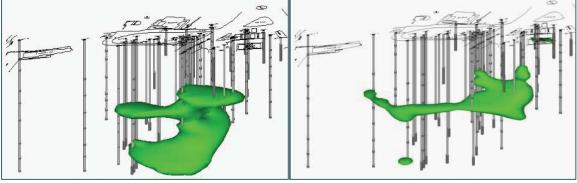
Three angled wells were installed beneath the road from the off-site property to conduct ISCO upgradient of the residential properties while avoiding the expense and difficulty of drilling in the state highway. The wells were installed at a 45° angle using sonic drilling to minimize smearing of the borehole and to drill through cobbles and the dense glacial till.

These wells performed very well during subsequent ISCO injection events. The effective radial influence of each well was estimated to be 25 feet and the injection flow rates were high relative to the conventional injection wells in use at the site. These wells allowed the injection of oxidants directly into the hot spot, reducing both the mass and concentration of the COCs. In addition, silt could be effectively removed from the wells using the Max-Ox Group's advanced development tools.

Results

A total of 6,800 gallons of hydrogen peroxide and 6,565 pounds of persulfate was injected during five injection events. Groundwater concentrations within the areas of greatest impact decreased significantly since initiating full-scale ISCO at the site. Benzene and MTBE concentrations in the center of the plume have decreased by one to three orders of magnitude. All monitoring wells meet the interim cleanup standard and the residential volatilization criteria, and there is no risk to the closest potable water supply well. Based on the successful reduction in the mass and concentration of the contaminants of concern, no additional remedial activities are required for the site.

Three-Dimensional Visualization of Benzene in Groundwater (1 ug/L isocontour)



Pre-injection

Post-injection

Cleanup of Large MTBE Plume in Twelve Months

Regulatory approval of system shutdown

Location: New York

Type of Site: inactive retail gasoline outlet

Constituent(s) of Concern: MTBE

constituent(s, or concerni miss		
сос	Avg Concentration in Groundwater (μg/L)	
MTBE (shallow overburden)	1,000	
MTBE (potable wells)	37	

Media of Concern: soil and groundwater

Lithology: 10 - 18 feet of fine- to medium-grained sand underlain by fractured amphibolite and granitic gneiss bedrock

Remediation Methods:

in-situ chemical oxidation (ISCO) via HypeAir-EX® continuous ozone and hydrogen peroxide injection

Effectiveness:

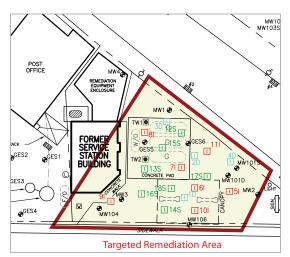
COC	Avg Reduction	
MTBE	99%	

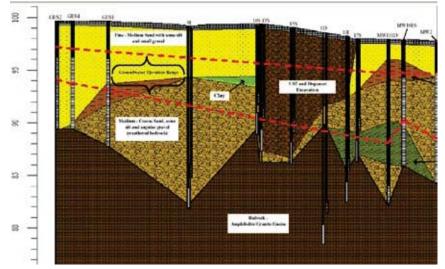
(dissolved-phase MTBE concentrations in shallow, intermediate, and deep intervals)

Case Study

MTBE was detected in the potable well at an active retail gasoline station in March 2000. Site investigation activities identified onsite soil and groundwater impacts on site and offsite dissolved-phase MTBE impacts. Over 100 residential water treatment systems were installed due to dissolved-phase MTBE concentrations. The UST system was removed and the station closed in 2002. In August 2000, an oxygen-only injection system was installed. After $2\frac{1}{2}$ years of operation, concentrations of up to 3,500 µg/L of MTBE remained on site. This system was replaced with a HypeAir-EX® continuous-operation in-situ chemical oxidation (ISCO) system in March 2004.

The HypeAir-EX system was designed to further remediate dissolved-phase BTEX and MTBE within areas where oxygen-only injection was conducted, while also treating additional impacted areas of the site. The shallow sand, intermediate weathered bedrock, and deep fractured bedrock intervals were targeted by 18 nested Max-Ox injection wells for injection of hydrogen peroxide plus ozone injection at the rate of 8 lbs/day. Regulatory approval for system approval was received after 12 months of continuous operation.









HypeAir-EX ozone manifold system



Chemical Oxidation at Former MGP Site

The Challenge

GES utilized its aggressive HypeAir-EX in-situ chemical oxidation (ISCO) system for an 8-week injection event to address dissolved- and adsorbed-phase volatile organic compound (VOC) and semi-volatile organic compound (SVOC) impact, and residual dense non-aqueous phase liquid (DNAPL) coal tar remaining in a portion of the site. The objectives were to reduce contaminants of concern (COCs) in DNAPL, soil, and groundwater; eliminate potential migration of DNAPL; and remediate the downgradient dissolved VOC plume via upgradient source reduction and enhanced biodegradation.



GES Solution

A network of 12 injection wells was installed for an effective radius-of-influence (ROI) in the area of residual and free-phase DNAPL, as

identified by a laser-induced fluorescence (LIF) survey conducted prior to system startup. The ISCO remediation system consisted of continuous operation of an ozone generation system for the injection of ozone and oxygen, as well as hydrogen peroxide periodically; bioremediation enhancement via hydrogen peroxide and ozone/oxygen/air injection; and active soil venting to prevent any potential accumulation of vapors in unsaturated soils.

During the ISCO injection event, an ozone/oxygen gas mixture blended with compressed air was injected into the well network. The injected air aided in dispersion and increased the ROI at each injection point. This oxidation process also promotes significant bioremediation outside of the injection area via increases in dissolved oxygen. Additionally, 10,000 gallons of 17.5% hydrogen peroxide solution was injected. Before, during, and after the injection event, DNAPL, soil, and groundwater sampling and laboratory analysis was performed. Operation and maintenance (O&M) of the ozone system, generator, and venting system was conducted on a weekly basis.

Client Benefits

Dissolved VOC and SVOC concentrations decreased over 95 percent during and after the ISCO event. Significant reductions of benzene and naphthalene were observed on site and off site, indicating a reduction in source impact on site. Soil headspace VOC concentrations decreased more than 86 percent after three weeks of system operation and more than 94 percent immediately following the injection event. Although some measurable DNAPL was present prior to the oxidation event, no DNAPL was observed at any site monitoring well following the two-month oxidation event. The site is currently in monitoring status.

site type

former manufactured gas plant site

location

Vinton, IA

contaminants

VOCs, SVOCs, DNAPL

project status

ongoing

technologies

HypeAir-EX chemical oxidation LIF survey

services

injection well installation remediation system design, implementation, and O&M DNAPL, soil, and groundwater sampling and analysis





HypeAir-EX in Weathered Bedrock at Active Retail Gasoline Station

sustained 99% average decrease in MTBE

Location: Pennsylvania

Type of Site: active retail gasoline station **Constituent(s) of Concern:** BTEX, MTBE

coc	Average Concentration in Groundwater (µg/L)
BTEX	366
MTBE	864

Media of Concern: soil and groundwater

Lithology: 10 - 18 ft of fine- to medium-grained sand underlain by fractured amphibolite and granitic gneiss bedrock

Remediation Methods:

in-situ chemical oxidation (ISCO) via HypeAir-EX continuous ozone and hydrogen peroxide injection

Effectiveness:

coc	On-site Average Reduction
BTEX	98%
MTBE	97%

Background

The Max-Ox Group was contracted to provide remediation of a historic release of unleaded gasoline at an active retail site.

Constituents of concern were adsorbed- and dissolved-phase BTEX and MTBE. The investigation identified significant MTBE groundwater impact up to 600 feet from the source area into a county park containing wetlands. The complex site geology consisted of clay and silt over weathered and fractured bedrock containing shallow and deep water-bearing zones. Bedrock was 15 to 17 feet below grade surface (bgs) on site and five feet bgs off site. A shallow overburden (soft weathered) water-bearing zone was perched above the bedrock surface and a deeper water-bearing zone within the bedding planes or joints of the underlying bedrock. Depth to water was approximately 12 to 15 feet bgs on site and 5 feet bgs off site. Injection wells were installed in shallow (overburden/weathered), intermediate (bedrock), and deep (bedrock) zones.

Since 1999, historical remediation activities utilized a shallow groundwater collection trench for groundwater extraction. A feasibility test was conducted to evaluate other technologies and address additional water-bearing zones. Air sparging (AS), soil vapor extraction (SVE), and in-situ chemical oxidation (ISCO) were tested in the field, and a combination of technologies was selected as the most appropriate and aggressive remediation technology. The selected remedy was ISCO

with SVE followed by AS proximal to the UST field after source area mass removal.



Remediation

A HypeAir-EX system was installed and activated in November 2004 to address the source area. The system was designed to inject ozone and hydrogen peroxide into 22 on-site injection locations, including eight Max-Ox nested points. The groundwater extraction system was decommissioned after startup of the ISCO system.

The SVE system operated until December 2005, recovering approximately 1,990 pounds of vapor-phase hydrocarbons. The AS system was operated from April through December 2005.

In June 2005, after seven months of remediation, on-site MTBE concentrations reduced from a maximum of 3,850 μ g/L to a maximum of 52 μ g/L. Eight of nine on-site MTBE samples indicated a reduction greater than 90%, and eight of 13 off-site samples indicated an MTBE reduction greater than 35%. Eight of nine BTEX samples indicated a reduction greater than 98%. Dissolved oxygen (DO) levels in the injection area increased to 10 to 16 mg/L throughout most of the source area. The MTBE plume length in bedrock decreased from 575 feet to 375 feet, and the BTEX plume length in bedrock decreased from 140 feet to less than five feet.

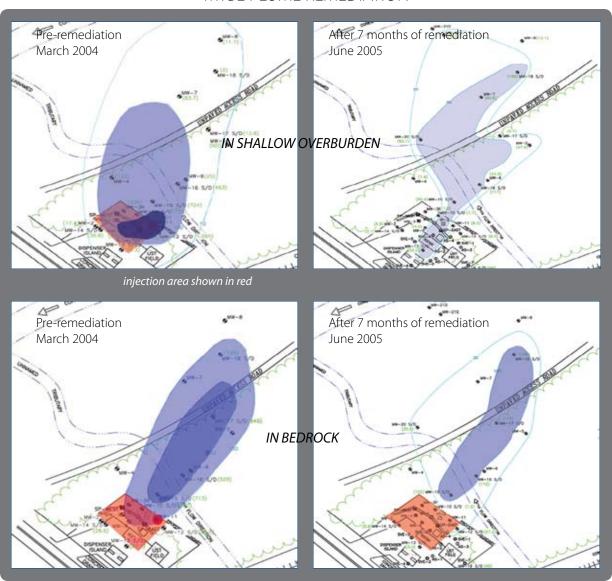
In September 2005, after ten months of remediation, the HypeAir-EX system was decommissioned. Ten nested Max-Ox injection wells were installed off-site for a series of twelve two-day injection events to directly address residual off-site impacts.

HypeAir-EX in Weathered Bedrock at Active Retail Gasoline Station

sustained 99% average decrease in MTBE

During the final six off-site events, Six-Phase Chemical Oxidation, using sodium persulfate to enhance the HypeAir process, was used to address some observed rebound in on-site MTBE concentrations. On-site groundwater quality data from September 2008 demonstrates a sustained 99% average decrease in MTBE concentrations from all nine monitoring wells relative to pre-remediation levels.

MTBE PLUME REMEDIATION





HypeAir at RCRA Site for **Toluene Polishing in Clay**

achieved cleanup goals for soil and groundwater

Location: Pennsylvania

Type of Site: printing facility

Constituent(s) of Concern: toluene

COC	Avg Concentration in Groundwater (µg/L)
Toluene	26,742

Cost: \$35,000

Media of Concern: soil and groundwater

Lithology: clay and silty clay

Remediation Methods: four two-day HypeAir events

Dissolved Toluene Concentrations

Effectiveness:

-RW-32

-RW-33

S-3

120,000

100,000

80.000

60 000

40,000

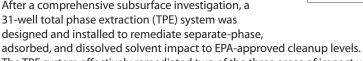
COC	Avg. Percent Reduction Post-Treatment
Toluene	96%

Background

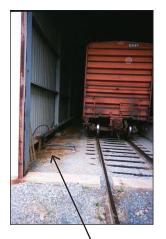
A printing facility required extensive remediation due to contamination by solvents including xylenes and toluene. Toluene was present at pre-remediation concentrations greater than 200,000 micrograms per liter (ug/L). RCRA corrective measures included investigation, design, system installation, operation and maintenance, and regulatory closure for three separate areas of impact. The soil type is clay and silty clay, and the depth-to-water is 8 to 12 feet below ground surface (bgs).

The removal of eight underground solvent storage

20.000 tanks and the disposal of more than 900 tons of soil as hazardous waste were completed within a two-week period to meet deadlines established by the PADEP. After a comprehensive subsurface investigation, a 31-well total phase extraction (TPE) system was designed and installed to remediate separate-phase,



The TPE system effectively remediated two of the three areas of impact within two years of operation.



Reaching Cleanup Goals

In the third area of impact, the system significantly reduced dissolved concentrations and the areal extent of the dissolved toluene plume, but it was unable to achieve groundwater cleanup levels. The Max-Ox Group's HypeAir® in-situ chemical oxidation (ISCO) technology was selected to polish the remaining toluene impacts present.

Four peroxide and air injection events were completed over a five-month period from August to December 2003. Injection activities were conducted within the railcar unloading area, requiring detailed coordination with the facility to minimize disruption to their operations. A total of 7,000 gallons of hydrogen peroxide was injected at 17.5% concentration. This achieved more than 95% mass reduction of the remaining plume.

Radius of influence (ROI) was limited to a range of five to ten feet during pressurized peroxide-only injections. The addition of air injection at 5 to 12 scfm increased ROI to a range of 20 to 25 feet. Cleanup goals were met for soil and groundwater set in the EPA consent order for all three areas of concern in 2007.



Injection conducted at wells located between wall and railroad tracks

www.max-ox.com